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THE TYPE OF THE PANAMA CANAL

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MEMBER OF THE ISTHMIAN CANAL COMMISSION OF 1904

UNDER the law of June 28, 1902, generally referred to as the Spooner act, which authorizes the construction of an interoceanic canal President Roosevelt appointed, in March, 1904, the following commissioners: Rear Admiral John G. Walker, U. S. Navy (retired), chairman; Major Genl. Geo. W. Davis, U. S. Army (retired); Col. Frank J. Hecker, of Detroit; Major Benjamin M. Harrod, civil engineer of New Orleans; Professor Willam H. Burr, of Columbia University, New York; Wm. Barclay Parsons, of New York; and the writer, of San Francisco.

The Spooner act empowers the president to purchase the canal properties upon the Panama route at a cost not exceeding $40,000,000, or, in the event of failure to do this, to enter into negotiations with the republics of Costa Rica and Nicaragua for a right of way on what is commonly known as the Nicaragua route.

Provision was made for the prosecution of the work of canal construction by the president, acting through and with the aid of a canal commission. An appropriation of $10,000,000 was carried by the act for use upon either of the two routes, and Congress was pledged to make additional appropriations as required up to $135,000,000 in case the Panama route was adopted and not to exceed $180,000,000 for work on the Nicaragua route. The secretary of the treasury is authorized to borrow from time to time, as funds may be required, the sum of $130,000,000, issuing therefor coupon or registered thirty-year bonds in such form as he may prescribe, redeemable after ten years, bearing interest at two per centum per annum.

The passage of the Spooner act by Congress, followed the submission of a report by the canal commission of 1899–1901, which recom-

UPPER SKETCH—LOCK CANAL. *A*, Colon; *B*, Limon Bay; *C*, mouth of Chagres River; *D*, Gatun Locks; *E*, Gatun Dam; *F*, Gamboa; *G*, Pedro Miguel Lock; *H*, Miraflores Locks; *I*, Ancon Hill; *J*, Sosa Hill; *K*, La Boca; *L*, Panama; *M*, Culebra Cut.

LOWER SKETCH—SEA-LEVEL CANAL. *A*, Colon; *B*, Limon Bay; *C*, mouth of Chagres River; *D*, Gatun; *E*, Chagres Diversion; *F*, Bohio; *G*, Frijoles; *H*, Gorgona; *I*, Matachin; *J*, Gamboa Dam; *K*, Empire; *L*, Culebra; *M*, Paraiso; *N*, Pedro Miguel; *O*, Miraflores; *P*, Corozal; *Q*, Ancon Hill; *R*, Sosa Hill; *S*, La Boca; *T*, Panama.

mended the acquisition by the United States of the rights and properties of the New Panama Canal Company. This recommendation was the direct result of an offer of the canal company to sell all its rights and properties for the sum of $40,000,000. The actual transfer of the canal properties to the United States took place on May 4, 1904.

The great engineering question before the commission, above named, related to the type of canal. Should the canal be built at sea-level or should it cross the backbone of the isthmus at the elevation suggested by the investigating commission of 1899–1901, and apparently contemplated by the Spooner act, with a summit level at 85 feet, or should it be a lock canal with some other elevation of its summit section? This question and the administration's course in setting aside the recommendation of a majority of the board of consulting engineers and adopting the plan of a lock-canal with a summit at the elevation suggested by the commission of 1899 and advocated by the minority members of the board of engineers are still fruitful of discussion.

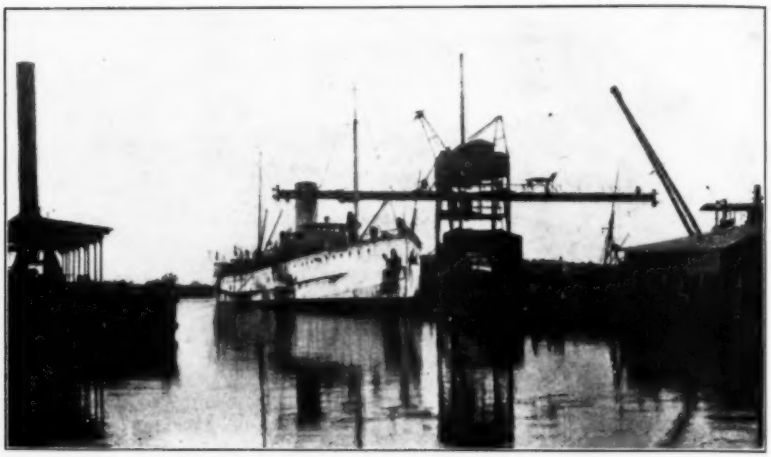
A review of the proceedings leading to the solution, and a presentation of some of the physical features of the problem, as disclosed by the proceedings, may prove an aid to a better understanding of the present situation.

Relating to the kind of canal to be constructed the law provides:

> The President shall then, through the Isthmian Canal Commission . . . cause to be excavated, constructed and completed, utilizing to that end, as far as practicable, the work heretofore done by the New Panama Canal Company, of France, and its predecessor company, a ship canal from the Caribbean Sea to the Pacific Ocean. Such canal shall be of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use, and such as may reasonably be anticipated, and shall be supplied with all necessary locks and other appliances to meet the necessities of vessels passing through the same from ocean to ocean. . . .

It was recognized by the commission of 1904 that under the Spooner act as quoted, a departure, to some extent at least, from the project which the earlier commission had outlined as a basis for comparative cost estimates was authorized and proper. It was incumbent upon the commission to determine whether a canal with summit level at 80 or 60 or 30 feet would not, all things considered, be better than the canal with summit level at 85 feet. It was therefore necessary to regard the entire question of type of canal an open one to be solved by the selection of that type and that summit elevation which would best fulfill all requirements. It was realized that this question required careful consideration from every standpoint, particularly in relation to its serviceability, to time required for construction, to first cost and to the cost of operation and maintenance with due regard to the importance of early completion, and reliability of service after completion.

In entering upon a preliminary discussion of these matters the lack



SEAGOING SUCTION DREDGE *ARCOH* TAKING ON COAL NEAR DRY DOCK AT CRISTOBEL.
This and other photographs are from the Annual Reports of the Commission.

of adequate data was sorely felt by the members of the commission and it was soon found that no satisfactory conclusion could be reached without supplementing by additional exploration with the auger and otherwise, the information disclosed by records of surveys, borings and shafts, which had been made by the engineers of the French canal companies. There had been no explorations to sea-level by shaft or by borings in the central sections of the canal yet this information was now of paramount importance for the determination of safe slopes for the sides of the deep cuts. In the absence of such information no satisfactory conclusion could be reached relating to the amount of material that would have to be excavated to maintain a great open cut at Culebra. The side slopes of this cut must be so flat that they will stand permanently. They should be as steep as they can safely be held in order that the quantity of excavation may not be unnecessarily increased. For the solution of this problem, it was necessary to know not only the character of all material to be encountered down to sea-level, but to a depth of over 40 feet below sea-level. Incomplete or unreliable data would throw more or less doubt upon the conclusions reached.

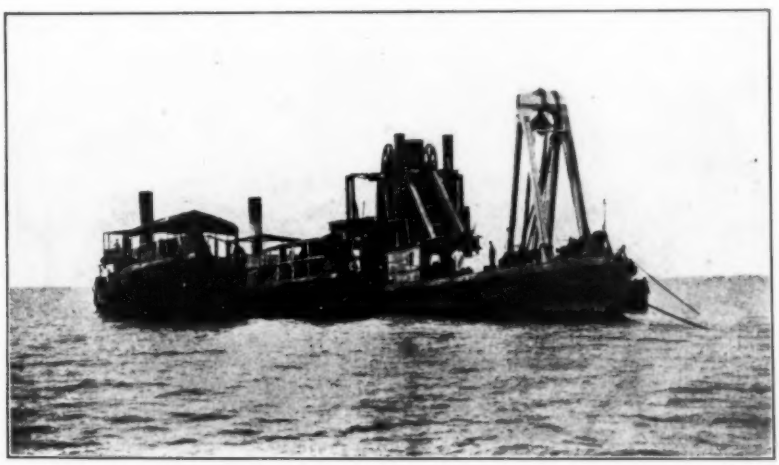
The commission of 1904, therefore, entered at once upon the collection of additional data and hoped to be able to reach an intelligent conclusion relating to the type of the canal at an early date. The published proceedings of the commission show that on December 8, 1904, seven months after the United States had taken possession of the canal properties, it was resolved to send the committee on engineering, consisting of Professor W. H. Burr, Wm. Barclay Parsons, and Major B. M. Harrod to the isthmus

to see that the necessary surveys and data for determining the type of canal have been completed and to bring the same to Washington to be laid before the commission; and that the committee on engineering plans shall, if possible, recommend to the commission, during March, various plans and estimates for the several types of canal, so that the commission as a whole may determine the same.

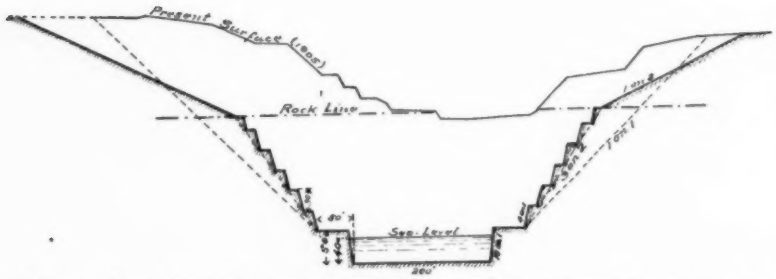
The writer was a fourth member of the committee on engineering plans.

In compliance with this resolution two members of the committee, Professor Burr and Mr. Parsons, went to the isthmus, where their deliberations were participated in by General Davis, who by virtue of his station on the isthmus was a member of all committees there in session. Major Harrod did not accompany the other members of the committee, because it was necessary to preserve a quorum of the commission at Washington for the transaction of business.

On February 23, 1905, the committee, having returned from the isthmus, made a report, in which it recommended that the construction of a breakwater at the entrance of Limon Bay should be commenced at the earliest practicable date; that the harbor at Cristobal should be deepened and otherwise improved; that, if a lock-canal be constructed the summit level of the canal should not exceed 60 feet; that Chagres River should be controlled by a dam at Gamboa; and that a plan for a sea-level canal, free from the restriction of locks (except a tidal lock near the Pacific Ocean) should be adopted. The committee included in its recommendations 150 feet as the least bottom-width of the canal and 35 feet as the least depth, suggesting, however, that estimates be also made to cover a depth of 40 feet. The committee also took up the question of the necessary lock dimensions, if locks be required, and advocated a width of 100 feet and a usable



OLD FRENCH LADDER OR ELEVATOR DREDGE DEEPENING ENTRANCE CHANNEL IN THE PACIFIC NEAR LA BOCA. This dredge is being served by two old French self-propelling hopper barges, known as "clapets."



TYPICAL CROSS SECTION ADOPTED BY THE BOARD OF CONSULTING ENGINEERS FOR THE CULEBRA CUT. K. 54.41.

length of 1,000 feet, but with intermediate gates to conserve time and water. The committee called attention to the increasing difficulties of constructing a dam at or near Bohio, disclosed by additional borings, and condemned as impracticable a dam at Gatun where borings to 172 and to 139 feet below sea-level did not reach bed-rock.

The data, which the commission had instructed the committee to bring to Washington, were not submitted with the report, neither did such data accompany a progress report of the chief engineer, Mr. John F. Wallace, which was received a few weeks later. The type of canal was, however, quite fully discussed by Mr. Wallace, and his report contained the recommendation

that no temporary or tentative plan be adopted that will interfere with the final adoption of the "sea-level plan," which it is hoped will ultimately receive the favorable consideration of the commission.

The committee report, however, brought before the commission a definite recommendation, relating to the type of the canal. In the

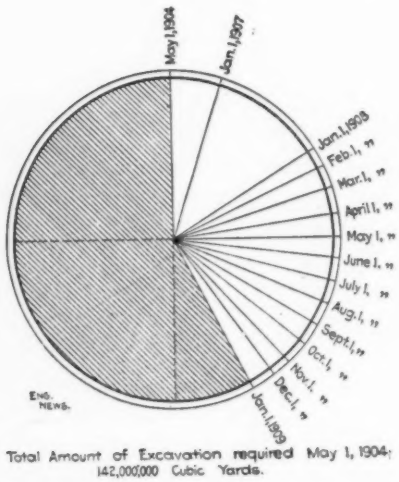


FIG. 1. PROGRESS OF EXCAVATION ON THE PANAMA CANAL UNDER THE UNITED STATES, AS COMPARED WITH TOTAL EXCAVATION REQUIRED.

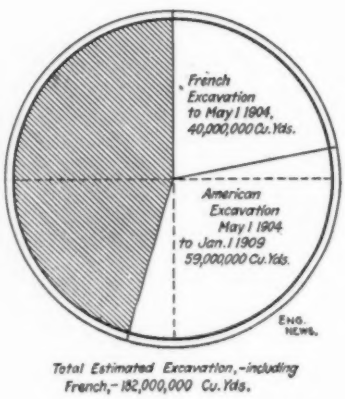

French Excavation to May 1 1904, 40,000,000 Cu. Yds.
American Excavation May 1 1904 to Jan. 1 1909 59,000,000 Cu. Yds.
ENG. NEWS.
Total Estimated Excavation, - including French, - 182,000,000 Cu. Yds.

FIG. 2. DIAGRAM SHOWING RELATION OF FRENCH AND AMERICAN EXCAVATION ON PANAMA CANAL TO TOTAL ESTIMATED AMOUNT.

absence of the data necessary to reach a final conclusion on this point, and in view of the fact that no embarrassment would result from a deliberate weighing of all the facts, the writer, though with a pronounced leaning toward the sea-level type, could not see his own way clear to an immediate concurrence in the conclusions of the committee. There was nothing convincing either in the report of the chief engineer nor in the report of the committee relating to quantity of material to be excavated nor in relation to probable cost. The writer did not then believe, nor does he now believe, that the steep slopes where the cut is deepest, as suggested by the committee, nor as incorporated in the plans now being carried out, can be adhered to.[1] There will have to be taken out ultimately very much more material than heretofore assumed at Culebra. This fact coupled with the concentration of the great mass of the excavation in a relatively short central section of the canal, which rendered preliminary estimates of time and cost of the removal of this material uncertain, was a factor that could not be ignored. When, therefore, at a meeting of the commission in March, 1905, it was proposed by Major Harrod that the recommendation of the committee be adopted and that the commission decide in favor of the sea-level canal the writer was not prepared to go so far and the committee report was referred to the committee on engineering plans, of which he was a member, for further consideration.

From these facts, as recorded in the printed proceedings of the canal commission, it might be inferred that at that time Major Harrod was in favor of the sea-level type of canal and that the writer favored the lock type. But the writer's stand was taken, as explained, to prevent action based on inadequate data, while Major Harrod is found eight months later among the members of the second canal commission who determined that the lock plan of canal, as recommended by the minority of the board of consulting engineers, is the one that should be carried out. And now the writer, after having had several years more time for reflection, and in the light of such additional information as has come to hand, is not yet convinced that the wisest course was pursued by the later commission, by the secretary of war, by the president and by congress when the findings of the majority of the board of consulting engineers, eight to five, were disregarded and the plans for a lock-canal project, as recommended by the minority, were adopted.

Before the committee on engineering plans made a report the Walker commission was superseded by the commission of 1905, whose powers were concentrated in an executive committee of three, at the

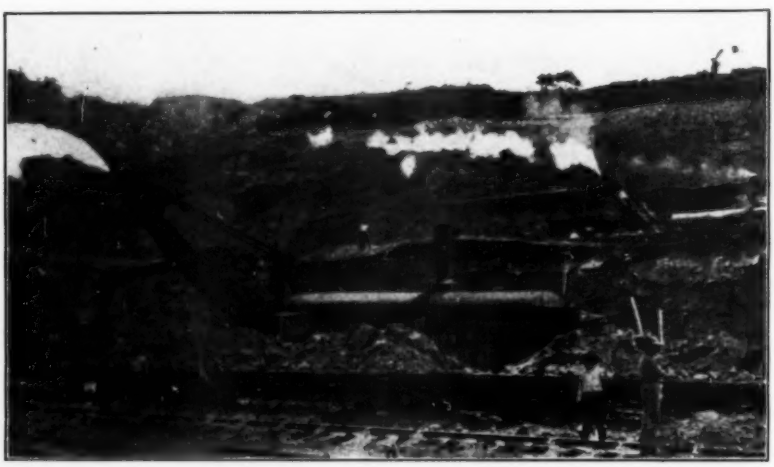
[1] Since this article was written information has been received that there has been much flattening of slopes. The standard section as shown in the illustration elsewhere presented is therefore no longer strictly typical of the section to which the canal will be finished.

VIEW IN CULEBRA CUT, NEAR EMPIRE, LOOKING SOUTH.

head of which, with dominating influence in the commission's executive affairs, was Mr. T. P. Shonts.

This commission was appointed on April 3, 1905. Two months later President Roosevelt named a board of consulting engineers, to whom he submitted the question of canal type. Thirteen engineers accepted the invitation to participate in the deliberations of this board of engineers.

The board, as finally constituted, consisted of: Geo. W. Davis, Major General U. S. Army (retired), chairman; Alfred Noble, chief engineer of the East River Division P., N. Y. & L. I. R. R.; Wm. Barclay Parsons, chief engineer of the New York Subway; Wm. H. Burr, professor of civil engineering, Columbia University; Henry L. Abbot, Brigadier



STEAM SHOVELS LOADING LEDGERWOOD FLATS ON EAST SIDE OF CULEBRA CUT JUST SOUTH OF GOLD HILL.

General U. S. Army (retired); Frederic P. Stearns, chief engineer of the Metropolitan Water and Sewerage Board, Boston; Joseph Ripley, general superintendent of the St. Mary's Falls Canal; Isham Randolph, chief engineer of the Sanitary District, Chicago; Wm. Henry Hunter, chief engineer of the Manchester Ship Canal; Eugen Tincauzer, Königlich Preussischer Regierungs-und-Baurath, Königsberg, Germany; Adolphe Guérard, inspector général des Ponts et Chausseés, France; E. Quellennec, chief engineer des Ponts et Chausseés and consulting engineer of the Suez Canal Company, France; and J. W. Welcker, Hoofdingenieur, Directeur van den Ryks-Waterstaat, The Netherlands.

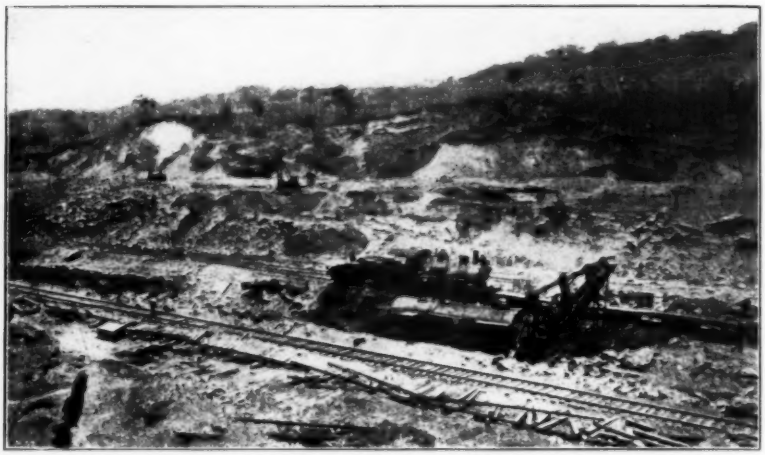
On this board of engineers were the three members of the first canal commission,[2] General Davis, Professor Burr and Mr. Parsons, who a few months before had submitted a recommendation favoring a sea-level canal. Other members of the board were known to favor a lock canal. The members of the board therefore naturally fell into two groups of which one was friendly to the sea-level, the other to the lock type of canal, and to the committees appointed from these groups was assigned the task of discussing the canal problem from the two divergent standpoints. The board as a whole, however, passed on certain features in order that the conclusions thus reached might serve as a guide in determining other features of the projects. Thus it was resolved that locks should have a usable length of 1,000 feet, a width of 100 feet and a depth of 40 feet. The board determined, too, upon the type and dimensions of the canal section which should be made the basis of a comparison of cost estimates.

The consulting engineers visited the isthmus and thus learned much, by personal observation, of the conditions under which the canal work must be prosecuted.

As a result of their studies the members of the lock-canal committee of the board of engineers submitted four projects. Two of these were for a canal with a summit level at 60 feet and the other two for a canal with its highest section at 85 feet.

Other projects for the lock-type of canal were presented by Mr. Lindon W. Bates, by Mr. P. Bunau-Varilla and by Major C. E. Gillette, of the engineer corps of the U. S. Army. Mr. Bates presented three projects with a preference expressed for a plan including a terminal lake at each end of the canal, of which the lake at the Atlantic end was to be formed by a dam at Mindi and the lake at the Pacific end by dams from Ancon to Sosa Hill and from Sosa Hill across the Rio Grande. Under this project there would also be an intermediate lake, formed by a dam across the Chagres River at Bohio. The summit level suggested was 62 feet.

[2] Of the other members of the first commission Admiral Walker had returned to private life, Major Harrod had been named on the second commission and the writer had accepted the position of chief consulting engineer in the Reclamation Service under the Secretary of the Interior.



LAS CASCADAS SLIDE, CULEBRA DIVISION, APRIL, 1908. AREA OF SLIDE, 5,433 SQUARE YARDS. Estimated amount of material in motion, 100,000 cubic yards. This slide started in the dry season and extended back 230 feet from the edge of cut and to within 50 feet of the crest of the hill.

Mr. Bunau-Varilla, a civil engineer who was at one time chief engineer, of the Panama Canal Company, proposed a project with a summit level at 130 feet; but with all locks so arranged that there could be a gradual progress of excavation and deepening of the summit level with a successive cutting out of locks until finally the lock canal was converted into a sea-level canal.

Major Gillette advocated a lock canal with its highest section at 100 feet above sea-level.

The sea-level canal committee of the board of engineers reported in favor of a canal 40 feet deep, with a bottom width of 150 feet in earth, and side slopes adjusted to the nature of the ground so as to give a surface width of 302 to 437 feet. The bottom width in rock was to be increased to 200 feet and the surface width in rock was to be 208 feet. At the Pacific end the canal was to be protected by a tidal lock located between Ancon and Sosa hills. The plans, as proposed by the committee, included a dam at Gamboa across Chagres River of either masonry alone or of earth and masonry combined. This dam was necessary for the control of the river.

The dimensions of the canal of the committee project at the point of deepest cutting near Culebra are as follows: Bottom width, 200 feet; the banks to have a batter of 1 in 10 rising from the bottom to a berm 10 feet above the water surface; the berm to be 45 feet wide (according to diagram; 50 feet according to text of report); then a succession of bank slopes with a batter of 1 in 4 and a rise each of 30 feet, one above the other, with intermediate berms each 12½ feet wide up to the rock line—shown by a diagram for the point known as Kilometer 54.41 in

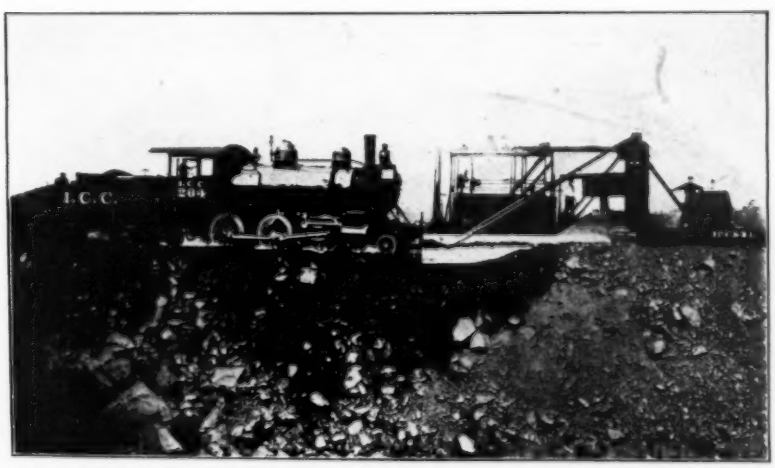
Culebra cut at about 170 feet above the water surface—thence to the natural surface with a rise of one foot in two.

In the course of its deliberations the board of engineers passed favorably upon the feasibility of a canal of either the lock or sea-level type. It determined that a lock canal with summit level at 60 feet should be the basis of comparison of the lock with the sea-level type. It reached the conclusion that about 10 to 11 years should be the time assumed to be necessary for the construction of a lock canal, with summit level at 60 feet, and about 12 to 13 years for the construction of a sea-level canal.

The quantity of material of all kinds to be excavated in constructing a sea-level canal was estimated at 231,026,000 cubic yards, and the estimated cost of making the excavation was $183,136,000.

Among the important considerations bearing upon the selection of the best canal type the board of consulting engineers, as noted in the majority report, says:

> The canal will provide the one great maritime highway, not between seas, but between oceans; not for countries, but for continents. The vastness of the interests to be served by the canal, many of which interests now wait for their development on the construction of the waterway, demands that the canal shall, when opened for traffic, be of the type which will most perfectly fulfil the purposes which the waterway is intended to accomplish.
>
> First and foremost it is essential that the Panama Canal shall present not merely a means of interoceanic navigation, but a means of safe and uninterrupted navigation on which no special hazards will be encountered by and no vexatious delays will be occasioned to the vessels which will traverse it. It is therefore evident that the canal ought to be formed in such manner that the course thereof shall be free from all unnecessary obstructions, and that no obstacles should be interposed in that course, whether temporary or permanent, which would by their very nature be an occasion of peril and of detention to

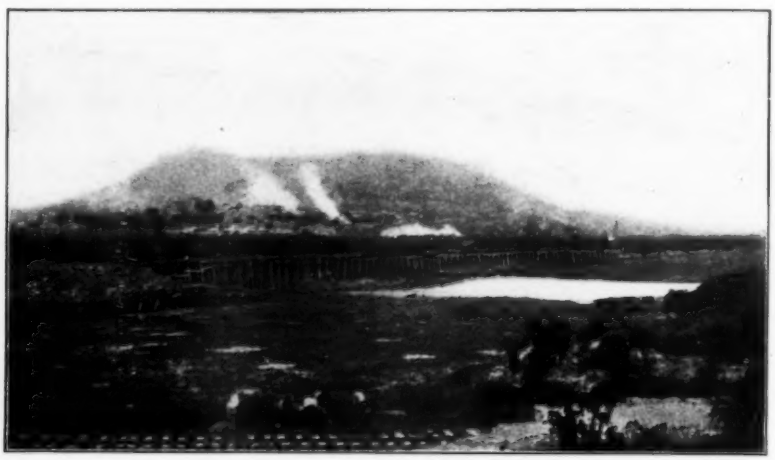


SPREADING MATERIAL ON THE COROZAL DUMP.

passing vessels, and more particularly to vessels of the great size which the Panama Canal is designed to accommodate.

The board is of opinion that this consideration should be of determining force in respect to the type of canal to be adopted, and that it should lead to rejection of all proposed plans in which lift-locks, whether few or many, form the principal or dominating features, and consequently to the acceptance of the sea-level plan as the only one giving reasonable assurance of safe and uninterrupted navigation.

The majority then set forth that no canal with locks can fulfil these requirements and that the sea-level canal is the only type of canal that can give reasonable assurance of safe and uninterrupted navigation. They refer to three accidents in the preceding nine years arising from collisions between steamers and lock gates on the "Soo," and to three accidents of a like nature on the Manchester Canal, and to the disastrous results that would have followed such accidents at the locks



TRESTLE DUMP JUST OUTSIDE OF EAST TOE OF THE SOSA-COROZAL DAM. Ancon Hill and Ancon Hospital buildings in the background.

of larger dimensions and higher lift on the Panama Canal. They placed the estimated cost of a sea-level canal at less than $250,000,000, and thought that it could be completed in twelve to thirteen years. They strongly condemned any provisional treatment such as the construction of a lock canal.

It is interesting to find among these members Mr. Hunter, the chief engineer of the Manchester Ship Canal (which is a lock canal), who in a convincing statement explains why, although as a member of the Comité Technique, he favored the lock canal as best suited to the conditions under which the New Panama Canal Company was operating, he is now in favor of the sea-level canal.

As an offset to the recommendation of the majority, a minority of five members, Noble, Abbot, Stearns, Ripley and Randolph favored a lock canal for the following reasons:

Greater capacity for traffic than afforded by the narrow waterway proposed by the board.

Greater safety for ships and less danger of interruption to traffic by reason of the wider and deeper channels which the lock canal makes possible at small cost.

Quicker passage across the Isthmus for large ships or a large traffic.

Materially less time required for construction.

Materially less cost.

The project recommended by the minority, which is the project as now being carried out (except for an enlargement of the locks, a change of lock locations, and the abandonment of the proposed dams on both sides of Sosa Hill at the Pacific end of the canal), includes a dam at Gatun, but none at Bohio, and no dam at Gamboa. The locks were to be 95 feet wide, 900 feet long, and the depth of water was to be 40 feet. The summit level was fixed at 85 feet.

Under the minority plan there were to be at the Pacific end of the canal duplicate locks of one lift of 31 feet each, and twin locks in flights of two at Sosa Hill.

The time required to construct the lock canal was estimated by the minority at about six years less than would be required for a sea-level canal, and the cost of the canal is estimated by them at $139,705,000. They say in their report:

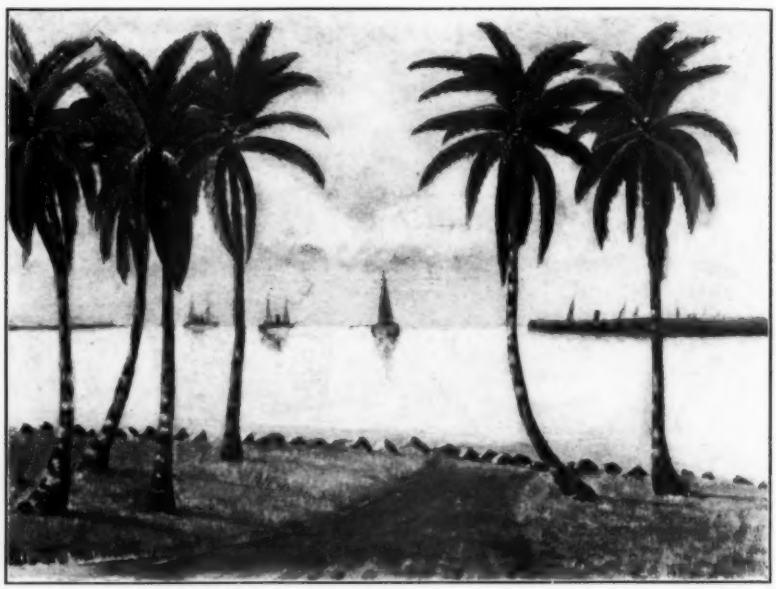
The greater cost of the proposed sea-level canal—upward of $100,000,000 more than that of the lock canal herein advocated—is not a trifling sum even for the resources of the United States. If such an outlay is incurred a greatly superior waterway should be obtained or the expenditure will be unwise and the result discreditable.

The minority then present their views at length, calling attention to the small risk of injury to a well-equipped canal lock; to the equal facility of protecting the canal against injury in time of war, no matter what its type; to the greater liability of delay and injury to shipping in traversing artificial channels at considerable speed than in moving slowly under perfect control through locks; to the greater speed at which the open water above the locks can be navigated; to the reduced time that will be required in the passage through the canal with locks; to the greater amount of traffic that would at the outset be provided for; to the provisions that can be made to prevent accidents at the locks; to the extraordinary dimensions proposed for the earth dams at Gatun and at Sosa Hill; to the fact that time required to make Culebra cut and to construct the locks is about the same. They estimate that six years less time will be required to build the lock canal than to build a sea-level canal.

At the time, January 10, 1906, the board of consulting engineers submitted their majority and minority reports to the Isthmian Canal Commission, the membership of the commission was as follows: T. P. Shonts, chairman; C. E. Magoon, governor of the Canal Zone; Rear

Admiral Mordecai T. Endicott, civil engineer, U. S. Navy; Brig. Gen. Peter C. Hains, corps of engineers, U. S. Army (retired); Col. Oswald H. Ernst, corps of engineers, U. S. Army (retired); and Benjamin M. Harrod. A vacancy in the commission that had been caused by the resignation of Mr. John F. Wallace had not been filled.

This commission determined on February 5, 1906, by a vote of five to one, to recommend to the president the lock canal project of the



LIMON BAY FROM THE DE LESSEPS HOUSE. Sketched April 10, 1904. The ships at anchor are the *Newark*, the *Montgomery* and the *Marietta*, all of the U. S. Navy.

minority of engineers. The dissenting member was Admiral Endicott, who favored the adoption of the sea-level project.

The recommendation of the commission was accompanied by a report of Mr. John F. Stevens, their chief engineer, who favored the lock-canal plan.

The secretary of war approved the recommendation of the commission and the president was not slow in acting. On February 19, 1906, the reports and papers were transmitted to Congress with a statement of his conclusions that the type of canal to be built is the canal with locks.

On June 21, 1906, the senate, by a vote of 36 to 31, passed an act authorizing the construction of a lock canal. This act was a few days later concurred in by the house without division. It provided

That a lock canal be constructed across the Isthmus of Panama connecting the waters of the Atlantic and Pacific oceans, of the general type proposed by the minority of the board of consulting engineers, created by order of the President under date of January 24 (June 24), 1905, in pursuance of an act

entitled "An act to provide for the construction of a canal connecting the waters of the Atlantic and Pacific Oceans," approved June 28, 1902.

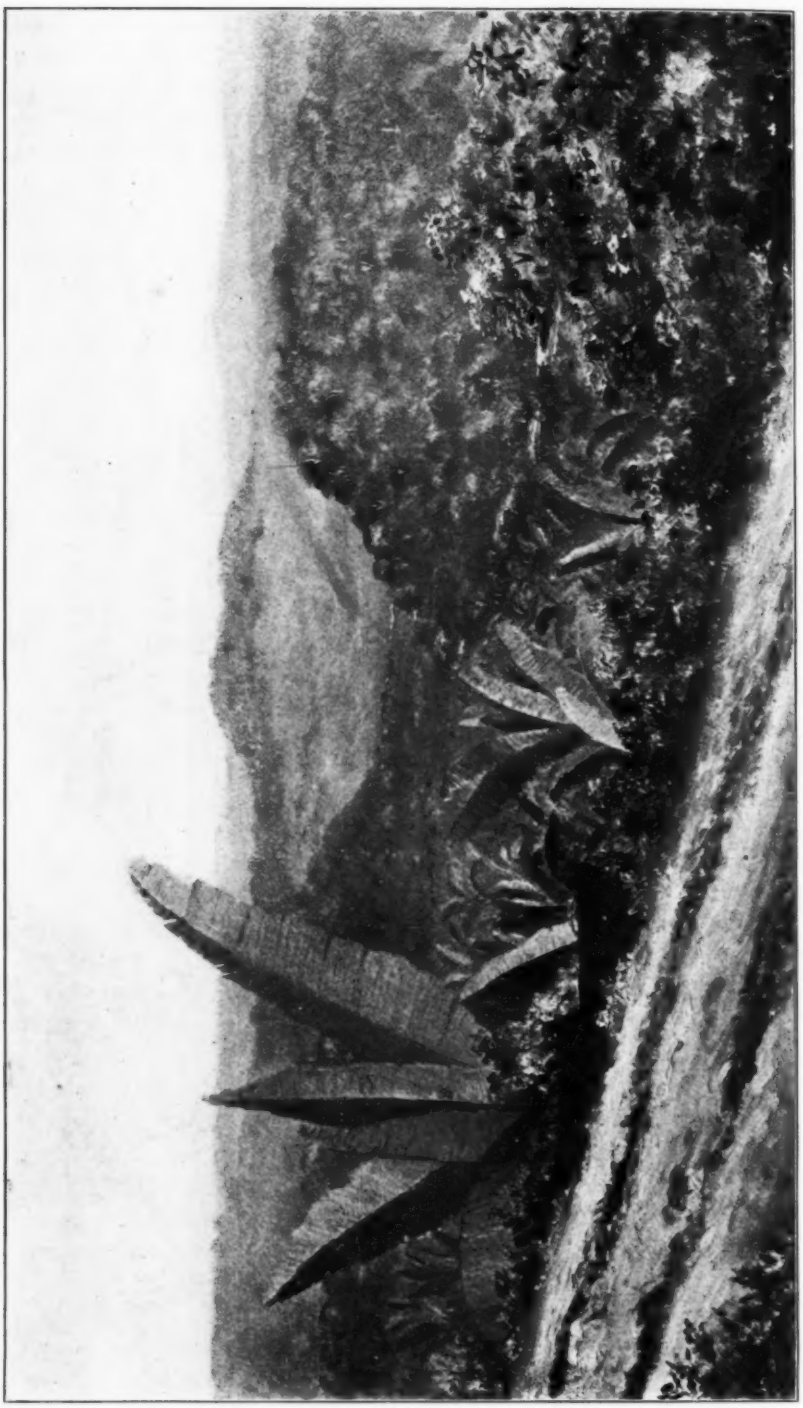
It has already been stated that the minority of the board of engineers recommended that the locks be made 95 feet wide with a usable length of 900 feet. The canal commission determined that larger locks would be desirable and fixed the width at 100 and the usable length at 1,000 feet. This action did not, however, satisfy the U. S. Navy. The question of still larger locks was agitated and resulted in action by the naval authorities upon whose suggestion it was finally decided to increase the width of the locks to 110 feet. The depth of water in the locks is to be about 41.5 feet; this will be the depth in fresh water which will be equivalent to 40 feet in salt water.

Since the final and specific approval of the lock-canal plan by Congress all the work on the isthmus has been directed to the rapid construction of this type of canal. Before presenting a few of the salient facts relating to the progress which has been made, a brief review will be given of the opinion expressed by some of the experts whose views were considered in reaching the conclusion that under all the circumstances it was best to build a lock canal.

It should be stated in this connection that the earlier conclusion of the Comité Technique, which was an advisory body to the New French Canal Company, favoring a lock canal, can be given but little weight, as an influence upon the later conclusion, because the advice of that committee was given to a private company operating under a concession with a time limit, and it was compelled to give paramount weight to the financial aspect. A canal had to be built under restrictions of time and cost, and it was to be made a profitable venture. It is not surprising, therefore, that under the new conditions, one of the members of that committee, Mr. Hunter, is found in 1905, as already stated, among those who advocate the sea-level canal.

Mr. John F. Wallace, a past president of the American Society of Civil Engineers, who was called from the position of chief engineer and manager of the Illinois Central Railroad to the position of chief engineer of the commission of 1904 and was later made a member of the commission of 1905, in addressing the board of consulting engineers pointed out:

> That the most desirable transportation routes are straight and level. Variation from the ideal may become necessary to overcome obstacles of a physical, financial or other nature. The plan usually selected is the one in which the sum obtained by adding the interest on cost of construction to the annual cost of maintenance and operation is a minimum. In the case of the canal the feature of future development should not be overlooked and any variation from the ideal of a straight or sea-level canal should only be made after the most mature and careful consideration and for the gravest of reasons. Minor deflections from a straight line are comparatively immaterial as compared with variations of levels.



NORTHEASTERLY ACROSS THE GATUN DAM SITE. Sketched in 1904.

Mr. Wallace formulates certain propositions which he considers fundamental and others which are essential in arriving at the most desirable plan of canal. He says that the most desirable canal is the sea-level canal of such dimensions as would afford unrestricted passage for the largest vessels afloat, with such margin for increase in size and draft as can reasonably be anticipated, making allowance for unexpected developments. No plan should be adopted that would prevent the ultimate construction of a sea-level canal at least approximately approaching to the final idea of the Straits of Panama. Time and cost should be considered to the extreme limit before determining upon a plan which would interfere with this ultimately desirable accomplishment. It is highly desirable that no dams should be constructed the foundations of which can not be carried to bed rock, or at least impervious curtain connection be made therewith. No high dam should be constructed, the destruction of which, by accident or design, would close navigation through the canal until its restoration. If it is absolutely essential to the project that such dams be constructed, they should retain the lowest possible head of water and be of such a nature as not to require the use of experimental, new or untried methods of construction. If terminal lakes are to be formed, the dams creating them should be as low as possible imposing the minimum weight upon the subsoil. The construction of even a low barrage at the Rio Grande Delta would undoubtedly encounter innumerable difficulties in crossing localities where the sub-formation would be such as to give way under the imposition of the weight of material placed thereon. The same obstacle would probably be met to a greater or less extent in the construction of a dam, particularly a high one, in the vicinity of Gatun. The entire valley to at least a depth of 200 feet is alluvial. It is therefore, highly improbable that in the heterogeneous mass of material with which the ancient gorge is filled, particularly near the surface, that unforeseen difficulties in securing proper foundation would not be encountered.

Mr. Wallace repeats to the board of engineers the recommendation which he had already made of the canal commission, that no temporary or tentative plan should be adopted that will interfere with the final adoption of the sea-level plan.

Mr. Quellennec, of the board of consulting engineers, at a board meeting on November 18, 1905, explained his stand in favor of a sea-level canal, stating that it was undeniable that a sea-level canal is preferable to a high-level multi-lock canal both with a view to safety and to facility of operation. He referred to his experience on the Suez Canal which has convinced him of the advantages offered by a sea-level canal. In spite of greater time and cost, he believes the sea-level canal at Panama should be constructed, but in making this statement

he does not wish to be understood as saying that a lock canal is not practicable.

At the same meeting, Mr. Hunter, of the Manchester Canal, gave expression to his views on the type of canal, explaining that although as a member of the Comité Technique he favored, under the circumstances then prevailing a lock canal, he could not under the altered conditions "undertake the responsibility of joining in a recommendation to the United States for the construction of a lock canal. . . ."

Advocating the adoption of a lock-canal project, on the other hand, Mr. Noble said:

> I believe the lock canal affords quicker construction, that the wider and deeper waterways it provides would give better navigation; that the transit of ships would be quicker and that the lock canal would have even a greater capacity for traffic than the narrow waterway proposed by the sea-level canal committee.

Another advocate of the lock type of canal, Mr. Ripley, concurred in the remarks of Mr. Noble and gave as an additional reason for his position the belief that this type of canal would provide for a navigation the limit of which will not be reached in a number of years probably 40 to 75 years, so that the people of the United States will not soon be called upon to make additional expenditures for improving the canal; whereas for a sea-level canal it is quite probable that within a short time, possibly 15 or 25 years, a widening will be necessary which will cost many millions of dollars.

Mr. Parsons, also of the board of engineers, referred to the fact that a canal was to be built for all time, that it was a work of the greatest constructive magnitude ever undertaken. The plan of the canal should be of the broadest and largest possible type which we can conceive. A few years more or less in time is of no consequence. Neither is an additional cost of $50,000,000 or even $100,000,000 of importance, as there will be an adequate return. Accidents similar to those which have occurred on the Manchester and the "Soo" Canals have occurred also in the Welland and other canals. These accidents by great good fortunes have not been disasters. With locks of large size

> of the size now contemplated the results would have been more serious. It is not the danger to the ship itself that I have in mind, . . . but the danger to the canal. If at one of these big locks an accident should happen, such as has happened at other locks and as will happen here, and a ship should go plunging through and carry away the safety gates and every other mechanical device for protection, releasing the lake of water that lies behind those locks, the section of the canal between that lock and the ocean terminas would be so destroyed that it would take anywhere from one to five years to put it back in service again. The terminal port itself would be gone, the canal would be out of use, the world's traffic would be deranged and the difference in cost of the two types would be wiped out in a few seconds of time. That risk a great government can not be justified in taking.

With these views before him, and in the light of all the information

then at his command, the president reached the conclusion that a canal with locks would best fulfil all requirements, and says in transmitting the board report to the Congress:

> In my judgment a lock canal as herein recommended is advisable. If the Congress directs that a sea-level canal be constructed, its direction will of course be carried out. Otherwise the canal will be built on substantially the plan outlined in the accompanying papers, such changes being made, of course, as may be found necessary, including possibly the change recommended by the Secretary of War as to the site of the dam on the Pacific side.

When the matter was before the senate committee on inter-oceanic canals, another opportunity was provided for the expression of views by experts. At these hearings, Professor Burr said that he was as strongly in favor of the sea-level canal as he ever had been.

> The more I reflect upon it, the more it seems to me that that plan is the one which the United States Government should adopt.

In discussing the Gatun dam, which is a feature of the lock-canal project as adopted, he says:

> It is proposed to build this dam by simply clearing off the surface material and then spreading the earth, suitably selected from the canal excavation, in layers, and so building it up to a height of 135 feet, making its base something like half a mile wide.[3] In my judgment, that is a dangerous experiment on a colossal scale, which this government is not justified in undertaking.

Continuing, Professor Burr states that he has no objection to earth dams under suitable conditions if properly designed and founded. Anything like a flow of water through the permeable material under the dam should be prevented. No suitable means for accomplishing this are provided in this design. He indicates measures that are ordinarily taken to check the flow of water under a dam, and instances several failures of earth dams. In speaking of the dams near LaBoca resting against Sosa Hill, the construction of which was subsequently undertaken, but owing to the yielding, unstable character of the marsh lands on which they were to rest, have been abandoned, Professor Burr says:

> The dams on the Pacific side are smaller, and the risks, perhaps, may be of less magnitude; but they are of the same character, and there is the same objection to them, in my opinion, This dam between LaBoca and the high ground opposite would be founded largely upon the most slippery kind of mud. Any one who has been there and has seen the bottom of the Rio Grande estuary exposed at low tide, I think will agree with me that it is a very lubricating material; and if you were to put a bank of earth on it, even if it were half a mile thick, I think it would be in great danger of being pushed out bodily.

In speaking of the operation of locks, he calls attention to the fact that the experience at the lock at St. Mary's Falls is not a safe guide for reaching conclusions regarding the safety of six such locks as will be required for the Panama Canal. Their lift is 50 per cent. greater,

[3] As now contemplated, the dam is to be constructed by the hydraulic fill method.

and the dangers increase at a more rapid rate than proportional to the lift, and the dangers are magnified by the fact that the locks are to be in flights. He furthermore reaches the conclusion that the traffic capacity of the lock canal should be estimated at about 35,000,000 tons per annum instead of at 80,000,000 tons, the figure assumed by the minority.

An extended and comprehensive argument for a sea-level project was presented to the senate committee by General Davis, who, as a member of the commission of 1904, and resident on the isthmus as governor of the Canal Zone for a year, and thereupon as chairman of the board of consulting engineers, had had unusual opportunity for arriving at a mature conclusion. All that General Davis said in relation to the type of the canal before the committee should be read by those who desire to follow this matter farther. Short extracts, and a condensed statement embodying the substance of his presentation, can alone be here attempted.

What the situation demands is well known, and the American government has declared to the world that the obstacle at Panama shall be removed. Will it be removed if we leave a hill over which the world's commerce and navies are to be hoisted? Will the world consider that we have adequately solved the problem, and will the American people be satisfied with the result if we offer them anything inferior as respects capacity, or convenience, or adaptability for enlargement, or type, to what capital did for the old world—a canal which now serves as a model, and will continue to, until we acquit ourselves of the responsibility voluntarily and eagerly assumed.

General Davis compares the Soo Canal, with its few thousand feet of channel approaches, to the great tidal harbor basins of Europe. It is more nearly analogous to these than to a great interoceanic canal on which the aggregate length of locks alone exceeds by nearly a mile the entire length of the Soo Canal. Because Lake Huron is twenty odd feet higher than Lake Erie, it was useless to hope for a channel clear of all obstructions, and American and Canadian engineers have provided the best solution possible.

At first, locks 350 feet long sufficed. Then one 515 feet long was added. Next, the first were demolished and replaced with a lock with a chamber 800 feet long. Then the Canadians made another in their territory 900 feet long; and we are about to demolish our second lock to put in one 1,400 long. . . . The critics of the majority report admit that a canal at sea-level would have certain advantages. I think it may be said that one and all concede that if a sea-level waterway be wide and deep enough, it would be superior to any involving excavated lakes, locks and lifts; but they discard it as impracticable because of the greater cost.

The better approach to the straight line requirement by the sea-level canal is pointed out. The lock canal project shows 21 per centum more winding and tortuous navigation than the sea-level project. General Davis estimates the expense of maintenance and operation of a sea-level canal at $1,550,000 per annum, and the lock type of canal, at $2,-

150,000. The cost of the government of the Canal Zone, estimated at $100,000 is not included in these figures. Relating to dimensions, and other features of various canals, data were presented in tabular form, in part as here reproduced.

EXISTING AND PROPOSED CANALS

	Units	Panama Sea-level	Panama Lock	Suez Now	Suez Enlarged	Kiel
Total length.....	Miles	49.35	49.72	94.76	94.76	57.89
Straight portion.....	Miles	30.18	42.25	81.73	81.73	
Curved portion.....	Miles	19.17	7.46	13.04	13.03	
Curved portion.....	Per cent.	38.8	15.0	13.8	13.8	40.9
Depth	Feet	40	40	31.2	34.4	29.52
Least bottom width	Feet	150	200	108.26	147.63	72.17
Least bottom width in curves.....	Feet	150	250	131	160[1]	75.2
Least cross-section..	Sq. feet	8,160	8,160	5,813 6,025	7,741 8,144	4,444
Total curvature.....	Degrees	597	637	467	467	
Curves.....	Number of	19	24	15	15	26
Locks	Number of	1	6	0	0	2
Locks, length.....	Feet	1,000	900			492
Locks, width.....	Feet	100	90			82

[1] Approximate.

The enlargement of the Suez Canal is not yet complete. The total length of the Suez Canal is 104.8 statute miles, of which about 10 miles are in lake, leaving the length of the excavated channel 94.76 miles.

The total length of the Kiel Canal is 60.89 miles, of which 3 miles are in lakes. Where two sets of figures are noted for the area of the cross-section, one applies to low, the other to high water.

General Davis shows that the proposed sea-level canal will not be dangerous, narrow or contracted, because this is not true of the Suez Canal, which is longer, narrower and shallower, and has more abrupt bends than the canal proposed by the majority of the engineers. He calls attention to the fact that in the opinion of very able engineers the cost in time will be but slightly more for the channel at ocean level, than for a canal with a summit level at 85 feet; and he says:

> It is certain that the cost in money of the simple low-level channel in which every existing and projected vessel would find convenient passage, will cost some tens of millions more than the complicated high-level structures, but the former will closely approach and ultimately result in the ideal, simple natural waterway . . . while the latter will stand for the opposite until heroic measures are resorted to and the objectionable structures are removed, for the idea of transformability is eliminated by the majority.

Col. Oswald H. Ernst, of the Engineer Corps, U. S. Army, a member of the canal commission of 1905, said in part:

> I have made a very careful review of the arguments presented on both sides, as exhibited in these two reports which you have before you—the majority and the minority reports—and I am satisfied that the United States will get a

perfectly satisfactory canal in very much less time, and for very much less money, under the plan proposed by the minority. I believe that the canal under that plan will cost little more than half what the canal of the majority will cost, and the time will be a little more than half, and when done it will be a better canal, because it will be three times as big a canal. The volume of water in the sea-level canal is only one third what the volume of water is in the lock canal. Leave out everything in those lakes beyond the width of 1,000 feet, and everything beyond a depth of 45 feet, and you have three times the number of cubic yards of water in the lock canal that you have in the sea-level canal.

Among the earliest and best-informed advocates of the lock canal is General Henry L. Abbot, of the Corps of Engineers, U. S. Army (retired), who was a member of the Comité Technique, and was also a member of the board of consulting engineers. General Abbot has been a close, able and careful student of the hydraulic and other problems involved, and ever since the days of the Comité Technique has contributed much to the discussion thereof. In presenting his views to the board of consulting engineers, which are at too great length to be quoted in full, he says:

The most important consideration, from an engineering point of view, in projecting a transit route, whether a railroad or a canal, is to adjust the details to the topography and natural conditions of the region to be traversed. On the Isthmus, the Chagres River is the dominating feature. . . . The deep excavation in the Culebra section is a formidable undertaking, chiefly because it will be necessary to transport the soil to long distances; but once executed, it will remain without giving occasion for anxiety in the future. The Chagres is capable of becoming a very active enemy at any future time, unless effectively tamed by good engineering methods.

General Abbot thereupon discusses the peculiarities of this river, and its relation to the several canal projects. He reaches the conclusion that the problem of the control of the Chagres is solved by the lock canal project in a manner at once vastly better and vastly more simple than by the sea-level project. He expresses his judgment, however, that the primary consideration in choosing between the two projects "should be their relative merits as routes for shipping. The elements of time and cost are secondary, but too important to be neglected." According to General Abbot, double the cost and double the time should be allowed for the completion of a sea-level canal, and when completed, the canal would be distinctly inferior to a canal with locks. In the matter of the sufficiency of the flow of Chagres River to maintain the lake above the Gatun dam, at the desired elevation, General Abbot is emphatically of the opinion that the water supply will be adequate. Based on a most

	Cubic Feet per Second
Evaporation loss, estimated	710
Leakage of gates	250
Infiltration	77
For light, power, etc.	200
Contingencies	200
Total	1,437

careful study of all existing data, on the assumption that the water surface of the lake will have an area of 110 square miles, he gives the following figures:

The water available is estimated at not less than 1,225 cubic feet per second natural flow at Gatun during the three months of lowest river stage, and to this amount there are to be added an additional volume of 1,577 cubic feet per second, resulting from a four feet allowable fluctuation of the lake surface. There are then 2,802 cubic feet per second available, of which the difference between 2,802 and 1,437, or 1,365 cubic feet per second, will be available for lockages. This amount of water, according to General Abbot, will be adequate for 26 daily transits. Should there be need for more stored water, the same can be secured by the construction of a dam at Alhajuela, where sufficient water can be impounded to increase the number of lockages by 40, though only 27 have been assumed by the minority.

It is absolutely certain that there can be no deficiency of water for any conceivable traffic demands.

Since the foregoing estimates were made it has been found that the Gatun Lake will have a surface area of about 164 square miles, instead of 110, as assumed. The lock dimensions have also been increased, as explained, and more water will be required for each transit through the canal. The estimates relating to the available water supply as above quoted therefore need revision.

And thus, in the light of the information then available, the type of the canal was fixed in 1906 by action of the Congress of the United States in substantial conformity with the recommendation of the minority of the board of engineers, and for three years the work of construction has been actively pushed.

The progress that has been made is clearly set forth in the records of work done. Measured by cubic yards of excavation it has been highly satisfactory. The graphical presentation herewith is from a recent summary published by the *Engineering News*. It appears from the figures compiled for that summary that the total excavation since the canal became the property of the United States at the close of the year 1908, amounted to 59,980,000 cubic yards, of which 53,161,000 cubic yards had been taken out of the canal prism, and 6,819,000 cubic yards were excavated from the locks and spillway sites and from other points outside of the canal proper. Of the total work, that done by steam shovels (work in the dry) amounted to 37,155,000 cubic yards, and dredges had excavated 22,825,000 cubic yards.

It has been estimated by the canal commission that the total excavation to complete the canal on the lines of the accepted project (not including the work by the French canal companies) is 142,000,000 cubic yards. According to these figures there were about 89,000,000 cubic yards yet to be removed from the canal prism on January 1, 1909.

It should be noted, however, that there has been little deepening of the canal excavation on the backbone of the isthmus,[5] at and near Culebra below the levels reached by the French companies. The work thus far has required the widening of the cut. Whether, hereafter, under the requirement for securing depth the same rate of progress can be maintained, as now shown by the records, is a question which can best be answered by the engineers now in charge of the work. It is probable that the future records will show a gradually decreasing rate of progress if measured by yards of excavation only.

When the building of the dams contemplated by the minority, from high ground at Corozal to Sosa Hill, was undertaken, it was soon found that these structures were ill-advised. The muck and mud of the "Manglares" could not support the load of a moderate fill. There was much settling and lateral displacement and the work was abandoned. This was in no wise fatal to the lock project, because it merely involved the shifting of the proposed locks at Sosa Hill back to Miraflores, where excavation for them is now in progress.

The work on the main dam, the dam at Gatun, has barely commenced. This dam will be of earth; it will have a crest length of about 7,000 feet, and a breadth of base, measured up and down stream, of nearly one half mile. The greater part of the material of which the dam is to be composed will be put in place by the hydraulic method. The material will be transported by water in pipes, and a practically impervious and safe body of earth will thus be deposited across the valley of the Chagres at Gatun. The recent settling and slipping of a rock fill that was being placed along the up-stream toe of the proposed structure is of no great significance. There will be other slips until displacement of layers of yielding material, under and particularly near the edges of such fills, is sufficient to secure stability. The doubts concerning the feasibility of a structure at this point have not arisen from fear of such slips, but from the uncertainty relating to a movement of water at considerable depth under the dam in porous deposits, the extent and permeability of which, notwithstanding information obtained by borings and shafts, must necessarily remain more or less conjectural. It is feared by some that such underflow may threaten the safety of the dam and by others that a serious loss of water may thus result.

All such fears are far-fetched. There is but little basis for them. There can be no injury to the dam from a moderate underflow if suitable precautions are taken to let the water come to the surface at the down-stream toe of the dam through sand, gravel and broken rock

[5] Information is published in the *Canal Record* of February 10, 1909, that the President in October, 1908, authorized the widening of the Culebra section of the canal from 200 feet on the bottom to 300 feet. This fact was not known when the above was written. The process of widening without materially increasing the average depth of this section of the canal may be expected to continue, therefore, some time longer.

deposits, so that it can not displace the earth particles with which it comes in contact in its passage under the dam. To make a convincing estimate of the volume of flow in the porous sub-surface strata under the dam is almost out of the question, because the extent, character and continuity of these strata can not be definitely ascertained, and it will be difficult, if not impossible, to determine at what point or points the water will sink from the lake above the dam into these layers. The engineers can, therefore, do no better than make unfavorable assumptions and determine the maximum water loss that may result under such hypotheses. There is no probability that this will be such as to prove embarrassing to the project. It is to be remembered in this connection that nearly always, when a subsurface flow in a river channel has been developed by the construction of a subsurface curtain or dam, the result in water output has been disappointing. In other words, the probability is that the under-flow will be over-estimated. Nevertheless, the public seems to expect further assurance that the canal work is progressing along proper lines, particularly as it now appears probable that the cost of the lock canal will be more than double the amount named by the board of engineers in comparing the cost of the two types of canal.

In the writer's opinion, it may confidently be assumed that a safe dam can be constructed at Gatun. The situation at Gatun is, therefore, of minor importance in the further discussion of the question that has again arisen: "Would it not still be well to change the approved project and to complete the excavation to sea-level?" This question, if it be again opened, will have to be considered in the light of the views of the experts whose opinions have been herein referred to, in the light of the work already done and the progress already made; in the light of the experience on the isthmus during nearly five years of effective work, and in the light of such additional facts and conclusions as may be submitted by the engineers now about to start for the isthmus.

January 25, 1909.

TARIFF REVISION FROM THE MANUFACTURER'S STANDPOINT[1]

By Dr. A. B. FARQUHAR,
YORK, PA.

MY experience as a manufacturer for more than half a century, an exporter and writer upon economic questions for about forty years, enables me to unite practise with science in demonstrating the truth of what I shall say to you.

The manufacturer's occupation, in common with most other occupations, has for its object to make money. As a social factor, his function is the elaboration of material, to meet the increasingly complex needs of a continually advancing civilization; but that and all else has to be subordinated, from a business man's point of view, to the endless task of investing smaller quantities of money and realizing larger; the difference of those two sets of quantities measuring his success or failure. He is a constructor incidentally—essentially he is a merchant. His great study is how to buy cheapest and sell dearest.

The tariff, considered as protective, is contrived and constructed with the single purpose of aiding the producer to sell dear. That aid is extended in part to production of mere raw material, but mainly to that of more elaborated articles, and the manufacturer has accordingly been always regarded as its chief beneficiary. Nor can manufacturers in general be fairly charged with ingratitude for the assistance it so graciously accords them in holding the hands of their customer while they rifle his pockets. But this grateful sentiment, though general, has never been quite universal; and the discordant voices, in the prevalent harmony, have of late grown more numerous than ever. The reasons for this—why the manufacturer is coming more and more to regard the tariff as not quite the most precious friend he has in this cold world—are, after all, very simple indeed. First, he comes to find, as his skill and facilities for production increase, that there is more profit in the greater number of sales to be had at a moderate price than in the smaller number at a high price, so that the ability to advance the price of his goods is, beyond a certain limit, no favor to him. A second and more important reason is that his interest is as much involved in buying cheap as in selling dear, and his "raw material" is always the finished product of some other producer, whose profits the tariff in-

[1] This and the following papers on tariff revision were presented before Section L—Social and Economic Science—at the recent Baltimore meeting of the American Association for the Advancement of Science.

creases, just as it increases his, by adding to the price of the article sold. Thus the same agency that helps him at one end hinders him at the other, and the hindering is usually greater than the helping. Why? Not because the tariff rates are proportionately greater on the material he buys than on the wares he sells, for they are in most cases less; but because anything that forces him to charge a higher price for his products in order to get the same profit from the manufacture and sale of each, must at the same time diminish the number he can sell. The wise manufacturer, like other sellers, looks for "small profits and quick returns," but returns are not quick when even a small profit necessitates a high price.

There are additional reasons, worthy of consideration, why the tariff is no such aid to manufacturers in general as it was designed and is claimed to be. It is not possible to depend for success on the favor of any government, autocratic or popular, and at the same time lead as vigorous and normal a career as when independent. One eye must be kept all the time on the business, and the other eye on the seat of authority—St. Petersburg or Washington. Part of the savings must be spent in keeping friends at court, or a lobby in the national capitol; or a subsidized press. Every congressional election must bring a fresh expense—a "frying of fat," as one United States senator termed it. But besides this waste of power, the cause in which it is incurred must suffer to an incalculable extent from the corruption which often attends (and is always suspected, whether discovered or not) the enactment of legislation from which individuals may derive a profit. Any deterioration of political morality tends to lower the self-respect of every citizen, and hurts business by lowering the public credit on which it is based. There is no proof that revisions of the tariff have been undertaken for the sake of the rewards that might be secured by those in charge of them, from the "favored industries" whose fortunes they are so powerful to make or mar; and probably there have been no such strokes of legislative enterprise in our history. But it is interesting to observe that the "friends" of the tariff, in whose hands we are so often exhorted to leave the entire office of amending it, have actually made a great many more revisions, generally upward—done many times more "tariff tinkering"—than ever have the friends of the mass of the people who bear the tariff's cost. The next revision will also be of the same character—by the friends of the system.

It is dangerous to invade the citizen's natural rights. The privilege enjoyed by some producers, of having all others taxed for their profit, delightful though this privilege may be to the possessor, is not a natural right, nor can years of undisturbed possession make it so. But the right to buy wherever one wishes to buy at the least attainable cost *is* one of the natural rights. The question of liberty of purchase is the same as of liberty of any other kind. There are the same excuses for restricting it, the same motives for maintaining it. To be

sure, there is something better than any liberty in an unquestioning submission to a higher guidance; greater than being our own master is unshaken loyalty to God as our master. Yet in practise, all attempts that have been made to find a ruler of a state, whose government could be in like manner better and greater than free citizens' government of themselves, have proved failures, and personal liberty remains a natural right—not because "the voice of the people is the voice of God," but only because of the imperfection of every accessible substitute. Perfect wisdom, we may readily admit, would easily guide us to purchase more wisely, and make a better selection of persons to purchase from, than is possible to our free choice; but it is absurd to look to the authors of tariff laws for such perfect wisdom, and our natural right remains. The country's defense occasionally calls upon its citizens for sacrifices of personal liberty, and may call sometimes for sacrifices of the liberty of purchase as well as other liberty. But to make the rare occasions when sacrifices are needed for defense an excsue for a perpetual infringement of this natural right—liberty of purchase—is preposterous. To maintain an oppressive tariff for such a purpose would be ridiculous, if it were not tyrannical. The only difference between this liberty and other liberty—an adventitious and not essential difference—is the facility with which the argument from patriotism may be applied against it. Yet in every such application we must see a confusion of thought, or exhibition of ignorance, unless we leave out of view the necessary reciprocity of international trade. Imported merchandise must about equal exported merchandise in value, unless there is an exceptional demand for specie in the country trading, or in some country trading with it, or unless the payment is made in service instead of merchandise in value, unless there is an exceptional demand for specie in the country trading, or in some country trading with it, or unless the payment is made in service instead of merchandise. The British, for example, always import a large excess of merchandise because they have a large credit balance abroad, from their services in ocean carriage, yielding five hundred millions annually, and even more from interest on foreign loans. Our own country, on the other hand, having "protected" its ocean merchant-marine to death, must export an excess of merchandise to pay for carriage both ways, and must also pay a heavy interest bill to foreign investors. The important point is that there is always a practical equality which our import taxation system can not disturb. Hence it follows that the so-called encouragement to foreign labor and enterprise in buying an article made abroad, is at the same time an equal encouragement to labor and enterprise at home required to produce the merchandise that is to go abroad to pay for it. It follows, also, that if we make ourselves, as is alleged, dependent on some foreign country by buying from it something that may be needed by us in warfare, we make some foreign country dependent

on us in the same act, for the commodity we must send abroad to effect the purchase.

Perhaps the most important condition of prosperity, to manufacturing and all mercantile business, is "Peace among ourselves and with all nations." There can be no reasonable doubt that continually shaping our policy with a view to possible war has a tendency to provoke war, among nations as among individual citizens; while the endeavor to increase the interdependence of nations, as of citizens, is a potent agency for peace. Free trade is thus a long step on the way toward universal peace, and as such it accords with the interests of mercantile business, as with the aspirations of all who believe in the Sermon on the Mount.

The question of the true interest of the manual laborer, too important to pass without a mention, is also too wide for adequate treatment within the limits here permissible. All other considerations might be banished from the problem, when once we convince ourselves which way the interests of the toiling millions point. If their interests demand a high protective rate of import duties, we might feel justified in adopting that policy, however objectionable it appeared on other grounds. But there is no real reason for separating the interests of the manufacturing operatives from those of their employers, and every business which would draw larger profits from cheaper raw materials and greater sales of cheaper finished products, would be sure to have more to pay its laboring men. As to the many times larger number of laborers in occupations not protected, because not subject to foreign competition or because able to meet it on its own ground by exporting, it is difficult to see anything but clear gain in the reduction of tariff duties for them. The most important of such occupations is the agricultural. Free trade is clearly to the advantage of the farmer, and whatever helps him will help those he employs. Every workman, in whatever calling, must be benefited by increasing the purchasing power of his wages, and the demand for labor in general must be increased by opening new markets abroad.

Some people pretend to believe, and some others may really believe, that free trade between countries having different wage-rates per day will tend to equalize those daily rates; but that is a fancy that finds no support in the realm of fact. It might be so if a day's work were everywhere under similar conditions and equally effective in production; but that has never been the rule, and with the increase of machinery it is becoming less and less the rule. The great difference in wage-scales prevailing in different sections of our union have established themselves and grown wider in the face of complete free trade throughout; the higher wages paid in Great Britain, with lower average cost of necessaries of life, as compared with all other countries of Europe, accompany a policy of free trade, and have advanced with it;

the protective system of the republic of Mexico or the continent of Europe has had no effect in improving the condition of laborers there; and—no end of instances could be brought to show that the supposed tendency does not exist. The only way to make out that it may exist is to ignore every test by facts. Wages are high in this country, for several good reasons; but a protective policy is not among them. Yet men even so intelligent as the manufacturers who appeared before the Ways and Means Committee, joined in protesting that they could only maintain their business, in the event of lower duties, by lowering their rate of wages. Unquestionably a lower price for the product, unless accompanied by considerably larger sales, argues either a lower total profit or a reduced cost of production; but why should these manufacturers look for their saving only to the payroll? Would they have us believe they are now paying their workmen more than the competition of other employers compels them? Or is their first thought always, in case of a business loss, to take it out of their men? As has been shown, they could not if they would.

There are positive reasons, moreover, for believing that a stronger demand for the services of the laboring man would naturally follow when we put our trade and industries into a more normal condition. It would be a benefit, surely, to cease to discourage the higher grades of industry by making their raw materials dearer. Even the protective nations of Europe—Germany and France and Italy—as well as Great Britain, adopt the expedient which Alexander Hamilton emphatically recommended as an encouragement to manufacture, admission of the raw material free of duty. Such a piece of barbarous stupidity as taxing the importation of raw wool, for instance, never occurs to European nations, although they raise many sheep. Nor do they put a penalty on shoe wearing by a tax on hides, or a premium on forest waste by barring out lumber. Again, we learn from the experience of Germany that lowering the duties on food is followed not only by a reduction in the laborers' cost of living, but by an increase in the government's revenues, and by increased merchandise exports, thus conferring a triple benefit. For another instance, we see the two Australian colonies, New South Wales and Victoria, characterized until 1901 by a difference in fiscal policy, adopted some thirty years before, and we find the free-trade colony, at first in the rear, now taking the lead in amounts manufactured and in income per capita. Once more, we are reminded by a prominent member of the British Parliament that in the twenty-eight years following 1879, when the Cobden treaty with France expired and when Germany definitely adopted a protective system, exports of British merchandise not only increased, but increased by a much greater amount, than during the thirty years that preceded; thus proving that free trade encourages exports, not only when other countries reduce duties at the same time, but also when the

whole world appears arrayed against it. The reason of this tendency of free trade to advance industry, as I pointed out, in an address before the International Free Trade Congress in London last summer, is "that every agency for reducing and obstructing importations must at the same time, a little less directly but precisely as powerfully, obstruct and reduce exportations."

It is altogether fallacious to treat the interest of the manual laborer as if it were something apart from that of the people as a whole—as if it were not practically identical with that of the consumer generally. Yet it seems peculiarly absurd to sunder the two in this case, because the main interest of the consumer, in cheaper and more abundant production, is one that necessarily and especially involves a great and steady increase in the demand for labor. That helps us to understand what so puzzled our great-grandfathers, the tendency of labor-saving machinery to bring prosperity instead of ruin to the working people. Free trade, now feared on exactly the same grounds as our ancestors feared labor-saving machines, will be sure to work the same way, as is proved by the last half century of English history.

A pretended connection of low-tariff legislation with panics and hard times has again and again been brought forward to befog the people's minds. It might be thought that the example seen a year and a half ago, of a business crisis occurring under the untrammeled sway of unmitigated Dingleyism, would cure any such notion. But since custom seems to devolve upon the tariff reformer the duty of accounting for all financial crises, it is worth while to say that the best explanation of that of 1907 appears to be the unnatural stimulus to protected industries given by the Dingley tariff, resulting in overproduction and a consequent glut, with which the inelastic currency system still surviving to curse our country was powerless to cope. But we must limit this degree of connection: if people are diligently enough taught to regard anything—no matter what—as the cause of panics, the appearance of that thing will produce a panic as the direct effect of the teaching. There is hardly even that connection between political economy and political boundary lines. It is everywhere conceded, probably, that a free exchange of goods is a benefit to our citizens throughout our northern territory, as far as the Canadian border. But why should there be an abrupt change across that artificial line, where conditions —except the color of bunting floating from buildings—are all the same? This reminds me of an old story of a German who lived, or thought he lived, in Pennsylvania, before the boundary was settled by Mason and Dixon. The border line, which he had believed to be just south of his house, was finally fixed a few lines north, and Hans was told that he now lived in Maryland. He replied: "I'm very glad of it, for I am told it is warmer in Maryland than in Pennsylvania."

The tariff, like national questions generally, ought to be settled on

the broad ground of principle. Fundamentally illogical, it is clumsy as a means of raising revenue, incurably inequitable in its application to the business of the country, corrupt and demoralizing in the way it is made into law, in the relation it forms between the government and the citizen, and in its creation of vested rights that too soon become vested wrongs. Hence arises a natural difficulty in discussing such a subject. Tariff revision? The only suitable revision is to revise it out of existence, except upon luxuries and articles coming under internal revenue taxation. It is difficult, also, to give serious attention to a complicated scheme of what Bastiat has so happily called "negative railways"—duties whose sole object is to increase the "friction of exchange," to heap up obstacles to commerce in the place of those which railways, steamship lines and good roads are provided and constructed to remove.

Considerably more force might be given to this general discussion by taking up some individual articles, such as iron and steel, or borax, or lumber, or wool, or hides, and applying the argument to it alone. Or a particular manufacturing business might be taken, as agricultural implements, or shoes, or carpets, and the effect of protecting its raw material be individually considered. Although the general principle applies throughout, it is quite natural that its illustrations should be easier to draw, and clearer to see, in some lines than others. Particular cases have been the theme of the weeks recently spent, and pages on pages printed, in the investigation by the Ways and Means Committee of Congress. With a general impression that that committee is likely to do as little as it can, it may nevertheless be fairly complimented on the interesting body of testimony it has heard and published.

Since the problem of tariff revision, here and now, is largely one of psychotherapy—how to "minister to a mind diseased"—since the only evil in tariff reduction is a direct result of the expectation of evil from it, just as panics result from a disappearance of confidence—the Ways and Means Committee method of looking for a solution may not be so hopelessly bad, after all. It is of vital concern to escape the general panic that might follow from the conviction of many men that lower duties would play havoc with them; and it is therefore proper enough to see and hear those men, and thus ascertain how delicately cases like theirs must be treated. Individually, no doubt, minds of this type are as little significant as the separate organisms that are collectively the cause of trichinosis, or typhoid, or cholera; but, like the same weak or undeveloped organisms, their number may be enough to give them a grave importance. Among the things that were with certainty predicted of this Ways and Means inquiry was that it would not recommend or introduce any measure that would reduce the percentage of protection to the excess of labor-cost of production in the

United States over that in Europe. This certainty comes from two sources: first, the difference in a large number of cases, even of high-protected articles, is the other way. The foolish assumption that a difference in wages per day means a precisely similar difference in labor-cost of articles produced, deserves hardly the honor of a refutation; for a real index of the fact, we can not do better than note, as did Mr. Carnegie, who is probably the best living authority on the subject, the confessed profits of the U. S. Steel Corporation: $133,000,000 net in 1907, on 10,000,000 tons of steel. They thus cleared $13.50 per ton, which, deducted from the selling price, leaves a cost-price lower than can be equalled in any country in the world. Every penny of that $13.50, above the "reasonable profit" that the world's competition would allow, is obviously a gratuitous bestowal of the people's money upon the trust; but our present concern with it is as a conclusive demonstration of lower labor-costs here than in Europe. The same is true, to a less striking extent, in the case of every product which is freely exported from this country. A second reason why we know that the committee will not apply this difference-in-labor-cost criterion is found in the absurdity of the principle itself. The little boy in the story, whose sympathies, in viewing a picture of Daniel in the den of lions, were especially called out by "that poor little lion in the corner, that was not going to get any of Daniel," seems particularly absurd when we first hear of him; but he was quite a master in protectionist logic. This criterion of labor-cost shows a very nice regard for the equities among the lions who are to feed on Daniel, and no regard for the prophet himself.

It would be interesting, also, to discuss the tariff before a scientific audience, as a purely scientific question, in a scientific way. This would involve, probably, an examination of the evolution of a national policy from a community policy, showing how each development on the larger scale had been long preceded by a similar development on the smaller. The question of division of labor, among members of a tribe, was probably as hotly discussed in its day as is the question of promotion or suppression of foreign trade in this; and quite possibly the arguments then made, on the one side and on the other, were very similar to those we now hear. The reason why no record of this ancient debate remains for us is doubtless that the decision was so complete and conclusive that it passed in a short time beyond the field of controversy; and so we may hope for the question of to-day—when the present pleas for industrial independence of nations shall have gone to join the old-time pleas for industrial independence of families, just as we expect national wars and war preparations and war policies to follow into obsolescence the continual tribal wars and hostile proceedings of the past.

TARIFF REVISION FROM THE MANUFACTURER'S STANDPOINT

By H. E. MILES

RACINE, WIS.

I WRITE as a Protectionist and a Republican. I believe thoroughly in the old-fashioned principle of protection to American industries and labor, as first accepted by Hamilton and Washington.

I understand that under our constitution money can not be properly legislated out of the pocket of a private citizen by Congress except for value received. I believe that the citizen does get value received from a tariff which gives to any desirable, well-managed industry a protection tariff which measures, in the language of Mr. Taft, "substantially the permanent differential between the cost of production in foreign countries and that in the United States." If it costs 90 cents to produce an article in Germany and $1.00 in New York, the New York manufacturer must be protected by the difference in this cost or must go out of business, leaving the American market to be supplied from Germany. The other alternative, that he cut his wages and lower the standard of living to his operatives is impossible.

I believe it pays the American consumer to maintain American manufacturing industries by whatever addition to price protection so measured requires. Also that this difference should be figured with that enlightened selfishness which ordinary prudence justifies. The duty, in the above instance, might well be 20 per cent., thus giving the American producer an advantage equal to 8 per cent. and causing the foreigner to pay this much for the privilege of entering our market and enjoying the protection of our laws, for the support of the government, etc. Protection of this kind steadies the home market, stimulates manufacturing, diversifies pursuits and should bring only beneficent consequences.

During this generation, politicians, economists and others in considering this question have seemingly spent all their time and energy in the discussion of the abstract theory of protection versus free trade. They have not got down to earth. They failed adequately to consider, or at least to emphasize and apply the principle of measurement above indicated, and from this omission came the opportunity for evil, of which special interests have made full use.

With public opinions overwhelmingly for protection, and no rule of measurement, it is small wonder that infinite loss and harm have come

to us as a people, economically and morally. If there is an honest rate in the present tariff I am unable to name it after two or three years of study, and if shown one I should be obliged to think it accidental. It could not have come upon careful consideration and exhaustive determination, for there has been no governmental process by which a rate could be made scientific and right. Our tariffs have been made by men almost wholly inexperienced in that work. Mr. McKinley, for instance, was the only man of previous experience among the majority members of the committee which framed the McKinley bill. The stories as to who wrote the schedules are scandalous, and, I judge, are true.

I know, for instance, that Mr. McKinley said to the head of an important industry: "Of course I do not know what rates you should have. You make them out and be fair about it." The gentleman addressed consulted others in his industry, and recommended some of his principal products for the free list because they were made more cheaply here than abroad, and were sold abroad higher than the domestic price. Mr. McKinley so recommended to his committee, but greedy men intervened and a miscalled protection was given in the bill of 65 per cent. It still bears about that rate and is still exported in large quantities at better than domestic prices.

So of the Wilson bill. Only three members of the majority upon that Ways and Means Committee, possessed previous experience and that as minority members upon the McKinley committees, where they had too great consideration for the majority even to be present when the real work was done. These three men with others wholly inexperienced made the Wilson bill. It was this so-called free trade Wilson bill that, by a wretched hocus-pocus, put Standard Oil upon the free list and gave at the same time a protective duty of 100 per cent. at an annual cost to the American people of about $40,000,000 per year. That lying "protection" was continued in the Dingley bill. When H. H. Rogers, manager of the Standard Oil Company, was asked how he got this protection from the "free trade" Wilsonites, he put his head back and laughed. There could be no better comment from his standpoint.

And from that day to this the Honorable S. E. Payne and John Dalzell have been on the committee "standing pat"—poker-playing as it were—with the people's money, playing the "game" with intent to lose, and losing in twelve years to the Oil Trust alone $360,000,000 of the people's money and to other trusts ten times more.

The free-trade Wilson bill also gave a high protection to sugar, and the sugar people offered money in large amounts for votes. The protection given them caused sugar stocks to advance ten points in forty-eight hours. Said President Cleveland of the Wilson bill—"Bought, bought, bought."

The Dingley committee had among its majority members only four men, Messrs. Dingley, Payne, Dalzell and Hopkins, a newspaper editor and three attorneys, and Mr. McMillan of the minority, with previous experience. That men so inexperienced should have hastily made a tariff for this nation was worse than a blunder—it was a crime. They only made a great blind jab at the task. They began wrong by taking classifications more than a generation old, inapplicable to their time. The committee had neither knowledge nor time to consider this important phase of the subject adequately. Consequently, we have had 30,000 lawsuits on the classifications of the appraisers, nine tenths of which might have been avoided. They put in one classification, for instance, buttons, stoves, electric fans, revolvers, nails, dress trimmings, railway cars and enameled portraits, cannon for war and crosses for churches. They were as careless as to rates. Said a member of the Ways and Means Committee in conversing with me upon this subject, "Why, when any one down in my district wants anything I get it for him, I get all I can, and that is all there is to it."

When Congress passed the Dingley bill it went into the trust-making business up to its eyes. A list which I have compiled of all the principal industrial trusts in the United States shows an absolute and complete disregard of the principle of measurement, or any other principle in the making of the schedules in which trusts are interested. A table showing the more important of these trusts was exhibited.

The tariff is supposed to be a protection to wages. This table shows that most of the trusts have tariff rates that are from one to fifteen times their total pay-rolls and yet the tariff should measure but little more than the *difference* between the American wage cost, per unit produced, and the foreign cost. In this sense these trusts have from fifteen to one thousand times a just rate. When Congress gives more than a just rate to any industry it invites, as a practical matter, those in that industry to form a trust and add to their prices as against the home consumer the difference between a fair protection and the excessive protection given.

Prohibition is not protection. An excessive tariff is usually prohibitive. It makes foreign competition impossible. The home producers by consolidation eliminate home competition and then have their 80,000,000 compatriots at their mercy. When, for instance, Congress put a duty of 45 per cent. upon goods I make, 15 per cent. being enough, it gave Congressional permit, if not a Congressional invitation, that all in my industry consolidate and add to our present domestic prices the difference between the necessary 15 per cent. and the 45 per cent. given. This is what all our trusts have done. The question whether any industry does add much or all of the tariff to its domestic prices is answered by this other question, "Can they?" If they can they do. Trusts can and trusts do.

As Mr. Carnegie has said, it may be taken for granted that the chief purpose in forming any trust is to raise prices. Industries operating under the old-fashioned principle of competition do not add tariff excesses to their prices, because they can not. In competition, and in that alone, is protection to the American consumer.

Government reports show that the Standard Oil, for instance, charges its domestic consumers 35 per cent. to 60 per cent. more for oil than it charges its foreign consumers. Domestic users pay about 40 per cent. more for files than foreign buyers of the American-made article. The foreigner gets American-made screws for about one half the price to the American consumer. Bar iron and other steel products are sold abroad at 20 per cent. to 40 per cent. less than home prices. It is a question whether ignorance is to be accepted as a congressional excuse. Said Zach Chandler, once a great senator from Michigan, "You may call me a thief, you may call me a liar, but, —— you, don't you call me a fool."

It seems impossible that our congressmen can have failed to understand that the marvelous profits our trusts make comes, in great part, not from the operation of plants, but from their manipulation of Congress itself, comes by vote of your congressman and mine, compelling you and me to make unwilling and forced contributions to trusts over and above fair compensation for their products.

It is pleasant for some to look toward Pittsburg and see the great flood of money rolling into its coffers, but look the other way. Trace the river to its sources, and you find the mighty flood dividing into millions of rivulets and at last each of them falling from a slit in a man's pocket—a slit cut by a congressman.

This situation has been brought about by the carelessness with which the American people regard their political interests, and by reliance upon the principle of competition, until recently sufficiently operative really to protect the consumer and make unnecessary scientific and exact procedure upon the part of Congress, in tariff-making.

This carelessness upon the part of Congress has now come to be practically intolerable because of the frightful excess to which many rates have been lifted. The walling in of 80,000,000 of consumers and their deliverance under an excessive rate to any who will and can "trustify" has led to the greatest exploitation of the public that has ever occurred in the history of any people. This hurt has come not only to 80,000,000 consumers, but in no less degree to the thousands of "intermediate consumers," the non-trustified competitive manufacturers who get their supplies largely from the trusts and are so overcharged as to be almost driven out of business. Steel, for instance, costs almost twice what it did when the Dingley law was enacted and the industry trustified. Those who use steel have been obliged to force their prices

up against the consumer until the latter all but rebels. Consumption is limited; margins are reduced. There are 216,000 manufacturing establishments in the United States. Of these about 175,000 are still upon the competitive basis. The trusts not only charge these competitive manufacturers excessive prices for their supplies, but they sell abroad at less price, so that such of these 175,000 independents as formerly competed to advantage upon highly finished products as against European manufacturers, in neutral markets like South Africa and the Argentine are now unable successfully to compete. They are losing out in foreign trade.

Also many trusts, those in steel and hides, for instance, own subsidiary corporations that compete with the independents. These trusts charge high prices for raw material and through their subsidiary companies make the finished product at so little above the price of the raw material as to leave no margin for the independents, who must either be given relief by tariff betterment or go out of business.

An excessive tariff like the Dingley is a blow at labor. This has not been sufficiently emphasized. A reduction in the tariff to the level required by Mr. Taft's principle of measurement will give the laborers of this country three chances for a raise in wages with no chances for a decline. This raise would come (1) through a lesser cost of living, (2) by increased employment, for with a lowering of prices must come an increased demand, (3) higher daily wages. A manufacturer can pay his employers only a part of what is left in the till after the bills for materials are paid. A return to moderate but ample protection will increase the profits of competitive manufacturers. In such increased prosperity labor always shares.

And so at the behest of trusts Congress made a tariff in the name of labor which has been a blow to labor.

None has been so befooled as the farmers. A glittering nickel, as it were, has been held before the farmer's eyes as it might before a babe's, and while he has looked at the nickel his pockets have been rifled of dollars. The farmer, for instance, has been given a tariff of 15 cents per bushel on corn, a product of which he has almost exclusive control, the crop of 1908 being valued at one quarter million of dollars. Last year the government raised tariff revenue the great sum of $2.78 on imports of corn from Cuba and about $1,400.00 from the rest of the world. Likewise as to eggs. Five cents per dozen protection, $27,000 imported and $300,000,000 produced at home. Against such trifling and almost insulting gift to the farmer, he is overcharged on his implements, on his clothing, on his shoes and almost everything he buys, overcharged in all about $250,000,000 per year.

The efficiency of the American mechanic has been wretchedly minimized. The character of our laboring population was splendidly evi-

denced in the last campaign. Mr. Taft said to labor, "I will give you what you deserve, neither more nor less," and that statement secured for him the biggest labor vote ever given a president. So always of American labor. Upon sober thought it wants what it deserves, neither more or less.

The statements made before the Ways and Means Committee within the last few days by those who wish to bolster wretched rates imply that it takes about two American mechanics to do the work of one European, as measured in wages. Except in tariff-making we hear that it takes two Europeans to equal one American. Let us not hastily declare that high wages and other splendid considerations given American labor are an economic loss. It pays to give men a good education; it pays to feed them well, to give them meat twice a day. Porterhouse steaks are good for a workingman, if he will only work hard enough to earn them. And ours do. Manufacturers usually say that their highly-paid men are the cheapest. This statement can be made internationally also. Said J. B. Sargent, a great New England manufacturer of hardware:

> I ship abroad most successfully those of my products which carry the largest amount of the highest paid American labor. I have little success with those which carry either cheap labor or little labor.

I mention steel and other important products only as examples. The tariff is as bad generally in textiles. For instance, it lays extra-heavy burdens upon the poor man's purchases and induces the sale of shoddy and cotton as good wool. It affects chemicals, even the medicines of the sick. It reaches in all directions.

As Mr. Taft has said, a doctor will not cut off a patient's head to cure a cold. We must not destroy in seeking to correct. The tariff must be taken out of politics and put into the hands of a semi-judicial, non-partisan commission composed of men especially of the highest integrity, who shall investigate schedule by schedule and report their findings in the form of recommendations to Congress and the executive. The right to make tariffs rests wholly in Congress; a commission can only recommend, as it did in Germany. We must believe that the Congress of the United States will legislate justly and wisely if only it is fully informed. The commission must be given authority and independence only that it may be efficient as the servant of Congress.

The commission idea is not new. There are hundreds, if not thousands, of commissions, national, state and municipal. Most of the great legislative reforms of this generation were based upon the findings of commissions. There is a tremendous movement now in favor of a tariff commission. We shall have one soon, it being only a question whether this next tariff will be based upon the findings of a commission or whether this tariff will be the last one to be made after the old fash-

ion. If it is to be made in the old way there is evidence already at hand that it will be based upon misstatements and misunderstanding. It will harm the public infinitely. It may lessen, but it will not abolish, the graft now estimated conservatively at $500,000,000 per year.

The public is thoroughly aroused and the work of reform is progressing as fast as ever any national movement of equal consequence. One of the most fortunate consequences of a justly protective tariff will be the tremendous enlargement of foreign trade. We pride ourselves upon the exportation of $1,082,000,000 of manufactured products, but 63 per cent. of these exports are crude and semi-crude; meat, petroleum, rails, billets, bar iron, lumber, cement, skins, etc. They contain 20 per cent. or less of labor. These are the very products needed by our own more numerous manufacturers at moderate prices for the employment of American operatives and the development into more highly finished products. With tariff correction, these semi-finished products will go abroad in higher forms with from two to five times more of good American labor in them. We shall become in larger and larger measure an industrial bee-hive, with our foundation world-wide and not to be shaken as heretofore by domestic panic. With this broadening of trade will come an intellectual and moral broadening and easement that will make us more truly the world power we sometimes affect to be.

TARIFF REVISION FROM THE IMPORTER'S STANDPOINT.

By FRANCIS E. HAMILTON
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THE exchange of commodities between the inhabitants of this world began at the point of time when original savagery first felt the influences tending toward semi-barbarism, and the purely physical control of man over his fellowman began slowly to yield to less brutal methods.

From that day, many thousands of years ago, until the present time, the advancement of civilization has been accurately measured by the state of commercial development, so that we now classify nations not by the numbers of their fighting men, but rather by the magnitude of their trade.

For a long period the free exchange and barter which sent Joseph and his brethren from Arabia down to Egypt and brought the Queen of Sheba to King Solomon's gates, ruled the known world over, and the caravans of Kenghis Khan or the sailor merchants of Cleopatra bought where they could buy the cheapest and sold where they could sell the dearest—duty free—be the market at home or abroad.

As the centuries passed and the people became less nomadic, the various nations were known each to each as producers of specific articles or classes of merchandise, and the tides of commerce began to flow in more fixed channels as the years ran. The spices of the east came westward for sale to the nations of Europe and the Atlantic coasts, while the stuffs and tapestries of Germany and Italy and the weapons of Spain found markets in both England and Asia. Except when some despot, requiring the gold to fill an empty exchequer, sold the privilege to trade in particular goods and thus created a monopoly, all the merchandizing from the beginning of the Christian era down to about 1600 was free and untrammeled of duty, either import or export.

From that time on, however, it was found that in various countries and with regard to various commodities, some restriction in the market and the method of their sale was necessary or the production languished and the goods disappeared.

The first duty laid upon goods coming into this country went into operation August 1, 1789.

The necessity for providing a national revenue was the first consideration with the new congress.

Within seventy hours of the opening of the organization James Madison introduced the subject of the Tariff, in part by the following words:

I take the liberty, Mr. Chairman, at this early stage of the business, to introduce to the committee a subject which appears to me to be of the greatest magnitude; a subject, sir, that requires our first attention and our united exertions. . . . The deficiency in our treasury has been too notorious to make it necessary for me to animadvert upon that subject. Let us content ourselves with endeavoring to remedy the evil. To do this a national revenue must be obtained; but the system must be such a one that, while it secures the object of revenue, it shall not be oppressive to our constituents. Happy it is for us that such a system is within our power, for I apprehend that both these objects may be obtained from an impost on articles imported into the United States.

In pursuing this measure, I know that two points occur for our consideration. The first respects the general regulation of commerce, which, in my opinion, ought to be as free as the policy of nations will admit. The second relates to revenue alone, and this is the point I mean more particularly to bring into the view of the committee. . . . The proposition made on this subject by Congress in 1783, having received generally the approbation of the several states of the union in one form or other, seems well calculated to become the basis of the temporary system which I wish the committee to adopt.

In closing, Mr. Madison offered a resolution declaring it to be the sense of the committee that specific duties should be levied on spirituous liquors, molasses, wines, teas, sugars, pepper, cocoa and spices, and an *ad valorem* duty upon all other articles; and also a tonnage duty upon American vessels in which merchandise was imported, and a higher rate upon foreign vessels.

From that day until this the United States has maintained a tariff. At times for revenue only, but in the main to produce a revenue and to protect home industries.

The act of August 10, 1790, was entitled "An act for laying a duty on goods, wares and merchandises imported into the United States . . . for the discharge of the debts of the United States and for the encouragement and protection of manufacturers."

It should therefore be noted that from the very inception of our government the tariff has been recognized as exercising two distinct functions; to wit, to raise a revenue and as well to protect home manufacturers.

Since the act of 1790 there have been passed by Congress thirty-three distinct tariff acts up to and including the act of 1897. Of these the McKinley act of 1890, the Wilson act of 1894 and the Dingley act of 1897, being the one now in operation, are those of most interest to the importer of the present day.

Probably no tariff act was ever placed upon the statute books that did not contain mistakes and that was not open to criticism from one source or another. The most equitable, the most liberal act must hurt some individual.

The importer who purchases his goods in other countries to sell at home, is primarily a free trader, and as such regards each per cent. of duty laid upon his particular importation as a tax upon his business. Sometimes he is so short-sighted as to consider his own particular

interests as paramount, and to forget the many intricate questions involved, all of which go to the proper conduct of the commercial scheme of an entire nation.

To-day the most experienced and intelligent business men are practically agreed upon the necessity of a tariff. The unsettled question which stands between the law maker and the importer is the rate. Both are now agreed as to the justice of the principle when equitably enforced; what remains is to agree upon what is equity to the importer, to the government, to the home producer and competitor and to the consumer.

I had the honor quite recently to suggest to the ways and means committee of Congress at one of the tariff revision hearings what I regarded as a "just tariff," which should be an act so drawn as to produce the needed revenue and at the same time protect home interests. Such protection should be equally divided between the capital that establishes, the labor that produces and the public that consumes.

I am still inclined to regard the definition both concise and correct.

Mr. Taft quite recently voiced his view of the tariff principle laid down in the republican platform in the following terms:

> The measure of the tariff should be the difference between the cost of production of the article in this country and such cost abroad, and in the estimate of the cost of production abroad and in the estimate of the cost of production here there should be included among other elements what is regarded in each plan as a reasonable manufacturers' profit.

With this the importer finds no complaint, as a duty fixed along such lines would leave open to reasonable business competition all the fields wherein foreign and domestic merchandise naturally seeks a common market. What the importer does object to is the establishment of a duty which either strangles all competition, thus creating a monopoly for home products only, or a rate so high that the so-called "reasonable" manufacturer's profit becomes unreasonable, forces the consumer to pay too dearly for his goods, either foreign or domestic, and inevitably produces "trust" control in the lines affected.

Such a tariff is unjust and benefits no one but the home producer.

Under it the importer must necessarily pay a heavy bonus for the privilege of conducting his business; the consumer is compelled to pay a high price for his merchandise; and it is always unjust to labor, since the rate of duty is never used as a measure by which to regulate the wage scale. The sole beneficiary is the home producer who is enabled to realize a profit drawn from the pockets of three classes, the importers, the consumers and his own employees.

One of the best examples of a violation of the basic principle set forth by Mr. Taft is the present tariff rate upon watch movements, imported in cases or without.

Fixed in 1897 through the efforts of certain interests in this country,

it has resulted in the creation of a watch "trust," producing millions of profits, even while the labor employed was often so poorly paid as to be unsettled and to have gone upon strike a number of times, and the consumer has paid for his American-made watch 20 per cent. to 30 per cent. more than the Italian, the Englishman, or even the Swiss paid for the same article purchased abroad.

That such a condition is evil, and that it should be corrected, all true lovers of their country will agree, but too often "What is every one's business is no one's," and tariff revision along this and a score of other lines equally bad can only be hoped for if the facts are placed before the Congress in convincing form.

It must ever be remembered that those who are now benefited through the protection of the tariff are on the alert to prevent any revision which will reduce their profits, whether reasonable or unreasonable, while the importer can, at the most, be only secondarily interested. He must continue business under existing conditions, although he would prefer a change, but those most interested and to whose benefit such a change would most conduce—the great mass of consumers, the people, are individuals busy with their daily affairs and unable to give the time or afford the expense which would be necessitated by any concerted effort to correct the existing wrongs.

And a great number of wrongs exist under the present act. It is somewhat of a popular fallacy that duties are levied only upon luxuries, and that the average citizen, the one who does not buy diamonds or automobiles and who has never made a trip abroad, has little or no interest in tariff questions.

That this is an error is easily proved by a glance at the act itself. There are 705 separate paragraphs, 463 of which, covering more than six thousand different articles, impose duties running as high as 60 per cent. *ad valorem*. The remaining paragraphs, 242 in number, constitute the "free list." In the minds of the general public the "free list" should contain all the necessities of life; as a matter of fact it covers less than half a dozen articles regarded as necessities, tea, coffee, needles, ice.

With all the remaining "free of duty importations" the average citizen has nothing to do. The wool which enters into the manufacture of your hat and your clothing pays a duty ranging from 4 to 12 cents per pound; the linen you wear or that is upon your bed pays 60 per cent. *ad valorem;* your stockings pay 30 per cent. *ad valorem* and the hides which are imported to make leather for your shoes pay from 15 per cent. *ad valorem* up. Gloves are taxed from $1.75 per dozen pairs to $4.75 per dozen, and jewelry pays 60 per cent. *ad valorem*.

We need to import but little food stuffs, as we are able to produce enough to supply our home necessities, but if we eat imported food we pay a tax upon it ranging from 10 per cent. to 45 per cent. *ad valorem*.

It will therefore be seen that the tariff is a subject that affects every citizen, even though he is unconscious of it, and that its revision is a matter of almost universal interest.

And because of the universality of this question it can be understood how vitally it affects all who are home producers.

The man whose business has grown up under the wing of a protective tariff will never admit that the original "infant industry" has become a lusty youth able to care for itself. He rather appears before the committee on revision and with simulated anxiety presents reasons why the protective rate should be increased, hoping doubtless by such tactics to prevent any reduction.

So general has this procedure become during the past two months while the ways and means committee have been holding tariff hearings in Washington, that lately when any one appeared before them requesting an increase in the tariff the committee would propound to him the initial query: "Are you making money in your business?"

One of the most striking examples of this pronounced selfishness on the part of the home producers was evidenced in the hearings under the paragraphs protecting oranges, lemons and olives.

A large delegation appeared from the California fruit growers, who presented to the committee among other things the statement that in the past twelve years the lemon growers had realized less than 5 per cent. net upon their investments and that unless the duty upon citrus fruits, lemons and oranges could be at least doubled, that is, made $1.60 per box instead of as at present, 80 cents, the California interest in these fruits would be destroyed.

In reply to such statement there was presented to the committee the annual report of the U. S. Government Pomologist for 1907, showing the cost per acre of maintaining the average lemon grove to be about $370.86 while the average production of one carload of fruit per acre sold at an average price during the past five years of $696.00 per car; thus making a net profit of about 90 per cent. annually; or allowing the cost of the land as given by the Californians themselves, *viz.*, $1,000 per acre, the annual returns would pay all yearly expenses and 32 per cent. upon the original investment.

No reply to this official "knock out" has been made by the citrus fruit growers, but it is not an isolated case. The rule is absolute that human nature, especially American human nature, gets all it can and keeps—if possible—all it gets. The public must look out for itself or fall under Commodore Vanderbilt's noted ban.

In the marts of trade no day passes that complaint is not voiced against the present tariff law. The mutations of eleven years have been such as to render scores of the paragraphs of that law and the duty rates imposed thereunder most inequitable and unjust. It is my belief that the so-called "good trusts" as well as the "bad trusts" have been

the natural outgrowths of the tariff, and I further believe that while the good trusts should be continued and their interests safeguarded for the benefit, not of the trusts themselves, or their thousands of stockholders, but for the interests of the millions of consumers, the "bad trusts" should be shorn of the power to rob those millions of consumers, which power is now largely theirs through the protection which the present tariff gives.

To arrive at this desirable end and as well to protect his own interests is the aim of the reputable importer, and because of the reasons given above, the necessity of producing the required evidence which will prove where the evil conditions now exist, and of submitting such evidence to the Congress, devolves upon the importer.

In the parlance of the day "it is up to him" to present to those engaged in the revision of the tariff all the data required to establish the injustice of any of the present duty rates and to urge the correction of the same.

The subject is the most important which has been before the Congress in the past decade. The prosperity of the country and its people, our commercial supremacy, our national credit, all largely depend upon the result of the present tariff revision. If the new bill, which may become a law by July 1, 1909, and which surely will become a law before January 1, 1910, is just and equitable in its provisions, we may look with assurance for many years of prosperity; if on the contrary the new act retains many of the evils which have grown up under the present one, if it is so drawn as to protect favorites and to slur over or fail to eliminate the wrongs now existing within its provisions, we may anticipate commercial unrest, if not disaster, and all the attendant train of calamities.

Tariff revision, therefore, from the importer's standpoint, is of the first importance. Greater than the Canal question—for our country will go on in its magnificent career whether the Panama Canal be completed in seven years or fifteen—greater than any political issue—for experience has taught us that the people right political wrongs in the long run—greater than any questions affecting our army and navy, our insular possessions, or even the future of our ex-presidents—the question of tariff revision goes to the very vitals of national life. And this being so, the importer finds himself suddenly thrown into the lime light as the spokesman for—not alone his own interests—but as well the interests and further welfare of all the people, the great body of the nation, the consumers, and as the champion for them and to protect and ensure them in their rights for years to come, he accepts the responsibility and seeks to supply our law makers with the enormous mass of facts, and the needed evidence which they require in order to produce a finished tariff act, one that shall be grounded in "favoritism toward none and justice to all."

TARIFF REVISION FROM THE CONSUMER'S STANDPOINT

By JESSE F. ORTON
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EX-REPRESENTATIVE Charles H. Grosvenor, of Ohio, while addressing the Ways and Means Committee, December 2, on tariff revision, used this language: "It is an unfortunate reference that is constantly being made to the wants and anxieties of the consumer. . . . The prosperity of the consumer goes hand-in-hand with the prosperity of the manufacturer." We have long been accustomed to the view that the consumer's interest is a subordinate one; but now mere reference to it is "unfortunate"; perhaps it will soon be criminal, or at least an act calling for social ostracism.

The majority members of the ways and means committee did not in terms echo General Grosvenor's sentiment, that the "wants and anxieties of the consumer" should be tabooed, but most of them showed their sympathy by action throughout the hearings. Representative Boutell, of Illinois, from the very first, set out to ascertain from witnesses what effect the lowering of duties would have on what he termed "the ultimate consumer"; and this phrase soon became a standing joke with the committee. One would have thought that surely there could not be, among the constituents of these congressmen, a single person so insignificant and vulgar as this same "consumer" must be. As most of the witnesses were protected manufacturers, they easily agreed that the consumer would not be helped by any reduction of duties, that the wicked importers would take all the benefits. When witnesses thought duties should be increased, as they frequently did, they were sure that consumers would not feel the "infinitesimal" burden that would be added, if indeed any were added. There seemed to be a sort of division of labor among the committee members, and it was Mr. Boutell's task to show that the misguided consumers of the country had no need for "anxiety," that they could not be helped by removing taxes or harmed by putting taxes on. Unfortunately, a few tax-paying goats were mingled among the tax-eating sheep that appeared before the committee, and their answers were not satisfactory to Mr. Boutell; they were very sure that the consumer was hurt by taxing the things he must buy and would be relieved by reducing the taxes; but the good representative from Illinois quickly forgot the discordant notes and went on calmly stating, day after day, that the unanimous opinion of witnesses was that the consumer would not benefit, etc., and expressing a hope that, before the hearings closed, the committee might discover

some schedule on which reduction of duty would profit "the ultimate consumer."

In showing up the folly of the consumer in supposing that he had an interest in the tariff revision, Mr. Boutell had an able assistant in Representative Gaines, of West Virginia. Mr. Gaines delighted in attempting to show that the duty, if it were all added to the selling price, would add very little to the cost of any particular article. For example, the duty on hides and leather meant only a few cents on a pair of shoes or a carriage top; and the duty on iron and steel meant only a trifle for each wagon. Plainly, it was his opinion that the consumer who would object to this small increase of cost was a very penurious fellow, one chronically disposed to find fault. As a rule, the committee members were careful to include in their reckoning only the added manufacturer's cost traceable to the duty. For example, they pointed to the fact that the duty on the leather in a pair of shoes is only about ten cents on the average, ignoring the profits that the wholesale and retail dealers must make on this ten cents, by which the added cost to the wearer of the shoes is made much greater.

There is at least one member of the committee who would not dignify the consumer's standpoint by the merest mention, Representative Fordney, of Michigan. The word consumer does not appear to be in his dictionary. He knows only the producer and regards as a blessing any duty whatever which prevents the importation of goods and compels their production in this country, no matter what may be the cost of producing them here. Here and there, among the majority members, there appeared a few indications of an appreciation of the rights and interests of the consumer. This was most noticeable in Representative Crumpacker, of Indiana, and Representative McCall, of Massachusetts, with an occasional gleam of light from Representative Hill, of Connecticut.

This general disparagement of the consumer's point of view did not seem to be the result of the old claim that the consumer does not pay tariff duties; but rather upon the consideration (1) that these taxes are small, (2) that the consumer derives great benefits from the tariff system, and (3) that if the taxes were removed, monopoly would prevent the consumer from getting the benefit. It seems to be generally admitted now that the consumer, and not the foreigner, pays the duty. One frank manufacturer said to the committee: "The consumer pays it and I am glad that he does."

If we were to inquire into the reasons why the representatives of the people at Washington are disposed largely to ignore the interest of the people as consumers, more than one answer might be made. To a certain extent, of course, this attitude is due to a peculiar economic belief, the acceptance of the protective theory, by which undue emphasis is placed upon the function of production at the expense of the corre-

lative function of consumption. But protection, as a theory, certainly is not directly responsible for all the indifference to the consumer. Honest and consistent protection, assuming that there may be such, would not in every case forbid the consumer to purchase cheaply abroad; but would, before levying a tax on the importation of an article, give some consideration to the question whether it can be produced in this country with reasonable advantage. In like manner, honest protection would give to producing interests only such a duty as would enable them fairly to compete with foreign producers, not an excessive duty which will exclude the foreign article and enable manufacturers in this country to exact, by combination or otherwise, unreasonable or monopoly prices from consumers.

It can not be doubted that congress has departed very widely from honest or consistent protection. That this is the inevitable result of the system of protecting private industries is my own belief; but that it is a necessary consequence of that system conjoined with our unrepresentative scheme of government, I think no observer at Washington can fail to see. Not only do selfish private interests nominate and elect congressmen and control their course in regard to legislation, but congressmen themselves do not blush to have it known that they are personally and pecuniarily interested in the levying of certain tariff duties for which they vote as public legislators and for which they work and lobby with all the skill at their command. If we had a high and honest standard of public morals in congress, it would be much easier to get an honest tariff, and the consumer would not be plundered as he is now. Whatever may be said of the personal character of congressmen as compared with the personal character of city councilmen, I venture to say that the publicly established moral code in congress is lower than in most city councils. In nearly all city councils a member is not allowed to vote upon any contract or other question in which he is known to have a pecuniary interest; and in many cities all members of the council are absolutely forbidden to have any pecuniary interest in any contract awarded by that body. In Washington it is common gossip, that, out of the nineteen members of the ways and means committee which will frame a new tariff, various ones are pecuniarily interested in this or that schedule; that one is interested in tobacco, another in olives, a third in lumber, and so on. Some of these personal interests cropped out at the hearings. Representative Fordney stated that he was engaged in the manufacturing of lumber, and he bitterly opposed all proposals to remove the duty from that necessity in the interest of 80,000,000 consumers and the conservation of the country's forests. Ex-Representative Rhodes, of Missouri, told how he had introduced a bill in a former congress, increasing the duty on barytes, while he was personally engaged in producing this mineral.

A considerable number of congressmen appeared before the com-

mittee as attorneys representing private interests and asking for duties on various articles. If a judge should descend from the bench and address the court of which he is a member, or a coordinate court, in the interest of private suitors, we should at once cry out against the system which made such an act possible. But in congress, representatives, whose votes will be needed when the bill reaches the house, appear before the committee in behalf of private parties; and senators, who will vote on the bill when it reaches that body, appear and ask for favors to certain private industries. At the recent hearings Senator Hale, of Maine, a member of the finance committee, to which the tariff bill will be referred and one of the most influential men in the senate, appeared in behalf of a duty on starch.

When the judges who are commissioned to sit at Washington and deal impartially between tariff-burdened consumers and tariff-protected producers, not only represent selfish interests, but are themselves pecuniarily interested in their own decision, what wonder is it that the consumer's interests are ignored. So far as moral quality is concerned, Senator Burton's act in representing private interests before one of the government departments, for which he was sent to prison, was mild and harmless, as compared with the acts which are openly committed by members of congress in tariff legislation. The one has been made criminal by statute; the others have not.

I have dwelt at some length upon the methods and means by which tariff revision will have to be obtained under present conditions. The situation indicates that unless the law-making body is constrained by an insistent and powerful public opinion, consumers are not likely to get any fair measure of relief. With reference to the specific relief that ought to be granted, something may now be said.

It is generally admitted that many existing duties are much higher than the difference in the cost of producing goods here and abroad. This difference in cost, considering reasonable profit as one of the elements of cost, is a test which the people are entitled to insist upon at this time. If it could be fairly applied, consumers would escape the payment of tribute to monopoly, although they might be injured by the protection given to certain industries that are not well suited to this country. Among the schedules that should be entirely removed, according to this standard, may be noted iron and steel, lumber, coal, lead, salt, petroleum and hides. Among those which will stand marked reductions, on the basis of relative costs, are sugar, many chemicals, woolen, cotton and silk goods, glass and earthenware, machinery and implements generally. We have, in the wool-raising industry, one that should be removed from the protected list on the ground that the duty is a burdensome tax on the people, without any prospect of developing a supply at all adequate for the needs of the country.

That these changes which I have mentioned, and others of a like character, would bring great relief to the consumers of the country, the whole people, I think, can not be doubted by any one who does not ignore the ordinary laws of trade. If the ways and means committee, or congress believes that some or all of the relief intended for consumers would be absorbed by trusts and combinations, by the thwarting of the laws of trade, these law-makers should be reminded that this is a poor excuse for their failure to remove burdensome and unjust taxes, that their proper function is to find a remedy for acts in restraint of trade, not to make fear of these wrongful acts the pretext for continuing oppressive burdens on the people.

If duties were reduced in strict accordance with the test relating to cost of production, using cost figures that now obtain, it would certainly be found that in the near future further reductions could be made in accordance with the same rule. This is so on account of the extent to which present costs in almost every industry in this country are increased by the tariff duties themselves, making materials and labor more expensive than they would otherwise be. Thus reductions in one industry will make reductions possible in other industries, until finally we may get down off from the unnatural level of prices caused by the extraordinary tariff rates which we have had for several decades. I believe that when we get down to natural conditions, we shall find that there are few industries that any longer need protection from the standpoint of actual inability to compete with foreign producers in this market.

I have spoken of results that might follow honest application of the test relating to comparative costs of production; but I regard this test as at best capable of only a very rough and imperfect application. Costs vary so much for different times and places, and the difficulty of getting real facts is so great, that this test, probably the best that can be offered in theory for "honest" protection, is wholly unsatisfactory to consumers and to the general public interest. This fact, with many others, leads me to reject entirely the system of protection, as a scheme which is incapable of honest application. Even if we should grant the essential economic arguments of the protectionist, the irresistible tendency of the system toward corruption of government, toward discriminating and excessive duties and monopoly, toward the encouragement of inefficient industry, would condemn it as one of the greatest forces for evil existing in our present civilization.

A PERMANENT TARIFF BUREAU: ITS RELATION TO CONGRESS AND PROPER PROCEDURE FOR TARIFF REVISION

By SEYMOUR C. LOOMIS

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FROM the six volumes of conflicting testimony given by over six hundred witnesses, during the six weeks' session of the Ways and Means Committee, it is evident that the framing of a new tariff law is fraught with many perplexities. It is important to make it, as nearly as possible, adapted to the accomplishment of the desired end. Frequent changes are to be avoided, because they upset calculations which are at the foundation of trade. Even if the object of a tariff is agreed to and settled, that object may not be attained by the means proposed. A tariff builder always has in mind one or both of two ideas or results; first, revenue with which to run the federal government; second, protection to domestic industries. These ideas may be, and generally are, antagonistic. A schedule which produces a large revenue may not be protective, and one which is protective may produce no revenue at all. Between these extremes there are numberless conditions where the relative amounts of revenue and protection change as the duty is more or less. And when the modifications of supply and demand and the variations of cost of production are considered the situation becomes worse than kaleidoscopic. Persons may even agree as to the principle upon which a tariff law should be drafted, and yet be hopelessly apart as to its application to a given case. The essential facts relating to many industries are hidden, and, if discovered, are not easily placed and held at their true relative value. They need to be coordinated with other facts relating to other industries here as well as abroad. Iron and steel enter into and form a part of so many articles, structures and things in general, that, it is claimed, if the price of those commodities was the same here as in other countries, foreign markets, now closed, would be opened to our manufacturers who use iron and steel as their raw material. This is also claimed concerning other staples. Whether this be true or false depends upon a great number of facts, which only an expert disinterested person can discover.

For these and other obvious reasons it is apparent that a corps of men in the employment of the government under the civil service, whose permanent duty it should be to probe into, obtain and correlate these facts, would be of great public advantage and utility. A perma-

nent commission, like the Interstate Commerce Commission, has been spoken of, which should have authority to investigate, and upon giving notice of from one to three years, to change the rate or schedule within certain limits prescribed by Congress, say from three to five per cent. A commission, however, with such powers would be unconstitutional. Article I., section 8, of the constitution provides, "The Congress shall have power to lay taxes, duties," etc. The power is given to Congress, and according to the familiar principle that no legislative body can delegate to any other person or tribunal whatever the power which was conferred upon it, such power can not be delegated to any commission. Congress must not only lay the tax and duty, but it must lay one which shall be uniform, definite and certain. It can not entrust the slightest modification or change to the discretion or judgment of any other tribunal. If a slight change in the tax can be made by a commission, then Congress can authorize it to make a great change. There is no middle ground. The entire power of laying taxes and duties is conferred on the Congress and that power can not be shifted. A commission is in no sense a representative body, and the right to lay taxes is, under our system of government, peculiarly limited to a body which is representative of the whole people. Such essentially is the Congress, to which the authority was given by the constitution.

All the benefits which would legally flow from a commission could also be had from a bureau of tariff in the Department of Commerce and Labor, and with less friction and more efficiency. Such a bureau could furnish data and memoranda with verifying witnesses, who could be examined by the Ways and Means Committee and by parties interested. In this way the whole people of the country would be represented before the committee in a substantial manner, where now they are practically unrepresented so far as the presentation of the case by witnesses and counsel is concerned. As a check upon the accuracy of the work of the bureau, parties interested should have the privilege of cross-examination, and also the right to bring before the congressional committee, which is independent of the bureau and of the department to which it belongs, experts of their own; these experts in turn to be subject to cross-examination by counsel representing the bureau of the tariff.

By such a procedure facts can be elicited upon which an orderly and scientific revision of the tariff can be made. These suggestions are not intended to unnecessarily postpone or indefinitely delay the present proposed revision of the tariff, but simply to indicate a method of procedure which should be made permanent.

JOSIAH WILLARD GIBBS AND HIS RELATION TO MODERN SCIENCE

By FIELDING H. GARRISON, M.D.

ASSISTANT LIBRARIAN, ARMY MEDICAL LIBRARY, WASHINGTON, D. C.

THE scientific papers of the late Professor Willard Gibbs, of Yale University, which have been brought together in a memorial edition by his pupil[1] and colleague, Professor Bumstead, furnish one of the most remarkable examples in existence of the value and fruitfulness of mathematical methods in scientific investigation. Originally printed in the scientific transactions of his native state, some of these papers have, by reason of the speedy exhaustion of their first imprints, been much sought after, but for many years practically inaccessible, except in French and German translations.

Gibbs was not, like Edison, Langley, Rowland, the inventor, experimenter or expert in delicate measurements, nor was he the great all-round physicist, like Maxwell, Helmholtz or Lord Kelvin. He was essentially and almost exclusively the mathematician, whose special function was not the discovery of isolated facts or new methods of experimental procedure, but the introduction of new currents of ideas; and it was the severe and rigorous form in which his ideas were cast that for a long period of time retarded their general adoption by the scientific world. If we accept Cayley's view that theoretical dynamics is in reality a branch of pure mathematics,[2] then the *opus magnum* of Gibbs, his survey of heterogeneous equilibrium, may be fairly accounted a legitimate triumph for pure mathematics.

The enormous growth of biological science in the nineteenth century has somewhat overshadowed the importance of the deductive and analytic methods which were the very life of the science of the past, and although mathematics, beginning with primitive man's attempt to count, lies at the basis of all his exact knowledge of the material world, its true function has not always been appreciated or even understood. The synthetic or Baconian method, of which we have such supreme examples in the work of Galileo and Darwin, must always appeal by its very simplicity to scientific men, since, instead of indulging in special assumptions and hypotheses, it has obtained from nature, by observation and experiment alone, facts which, as in the Darwinian theory, can be concentrated upon some special proposition to be induced with the surety of Moltke's tactical device, *Getrennt marschieren, ver-*

[1] J. Willard Gibbs, "Scientific Papers," 2 vols., New York and London, 1906.

[2] "Report British Association for the Advancement of Science," 1884, 20.

eint schlagen. As science aims only to classify, predict and control phenomena, it has no absolute philosophic certainty except as a logical interpretation of the empirical facts of man's experience, and of the relative limitations of mathematical deduction and physical induction it has been well said that "the former breaks down on the subtlety of nature, the latter on its imperceptibility."[3] Galileo's telescope, Leeuwenhoek's microscope, Lavoisier's balance, Kirchhoff's spectroscope, are doubtless of more practical value, but certainly not of more scientific importance than formal and symbolic logic, the calculus, determinants, quaternions, vector analysis or the improved formulation of dynamics. Without induction, it is true, no new facts; but without deductive methods there could be no interpretation of these facts, nor would scientists have the means of predicting other facts which go beyond experience, or of controlling phenomena. Yet an authority so open-minded as Professor Huxley, who seems to have confused mathematical methods with the scholastic reasoning and bigotry which opposed the great cause he championed, seldom lost an opportunity to say hard things about the science "which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation."[4] In Professor Sylvester's brilliant and memorable reply to some of Huxley's after-dinner denunciations,[5] "the most eloquent of mathematicians" retorted upon his adversary that his chaffing might have been more guarded "had his speech been made before instead of after dinner,"[6] and went on to show that the maligned science employs not only imagination and invention, but observation and experiment at need. Even mathematicians, Sylvester pointed out, occasionally make discoveries, as witness Eisenstein's discovery of invariants, which was happened upon by purely physical observation "just as accidentally and unexpectedly as M. du Chaillu might meet a gorilla in the country of the Fantees."[7] The touchstone of the matter lies in the one really telling remark that Huxley made about it, viz., that mathematics will not yield correct results if applied to erroneous data.[8] The advance of modern science is largely bound up with the perfection of instruments of precision, and we have learned from the teaching of Lord Kelvin and the writings of Poincaré to recognize that mathematical

[3] "Lectures on the Method of Science," Oxford, 1905, 12.

[4] Huxley, "Lay Sermons," New York, 1871, 168.

[5] *Ibid.*, 66.

[6] *Nature*, London, 1869–70, I., 237.

[7] *Ibid.*, 238.

[8] "Mathematics may be compared to a mill of exquisite workmanship which grinds you stuff to any degree of fineness; but, nevertheless, what you get out depends upon what you put in; and as the grandest mill in the world will not extract wheat flour from peascods, so pages of formulæ will not get a definite result out of loose data." Huxley, "Aphorisms and Reflections," London, 1907, 93.

science is itself a powerful instrument of precision, which, if applied in the right way to data of the right sort, may yield important results. Biologists like Loeb, Francis Galton, Karl Pearson, Driesch, physiologists like Helmholtz and Chauveau, psychologists like Wundt and Fechner, the leading physical chemists, van't Hoff, Arrhenius, Roozeboom, Ostwald, van der Waals, van Laar, Nernst, Le Chatellier, Bancroft, have all employed mathematics as a necessary part of their equipment, and more especially has knowledge been advanced by physicists like Maxwell, Lord Kelvin, Helmholtz, Hertz, the Curies, Stokes, J. J. Thomson and Gibbs, who have got at the more imperceptible aspects of nature by deductive methods "interlaced with physical induction and experience." In the discovery of radium by the Curies all the processes up to the use of pitchblende were inductive; after that every step taken was pure deduction, based upon the *a priori* assumption of an unknown substance. Maxwell could predict the existence of electromagnetic waves from his equations[9] at least twenty-five years before their actual demonstration by Hertz[10] and Gibbs's algebraic statement of the theorems of chemical statics was far in advance of their laboratory verification.

Ostwald, in his interesting "Biologie des Naturforschers,"[11] has divided men of science into two classes: The classicists (*Klassiker*), men like Newton, Lagrange, Gauss, Harvey, who, dealing with a limited number of ideas in their work, seek formal perfection and attain it, leaving no school of followers behind them, but only the effect of the work itself; and the romanticists (*Romantiker*) who, like Liebig, Faraday, Darwin, Maxwell, are bold explorers in unknown fields, men fertile in ideas, leaving many followers and many loose ends of unfinished work which others complete. In the logical perfection of his work and in his unusual talent for developing a theme in the most comprehensive and exhaustive manner, Gibbs was emphatically the Klassiker. But in the scientific achievement of his early manhood he showed something of the spirit of the Romantiker also. His mathematical theory of chemical equilibrium was, as we have seen, far in advance of any experimental procedure known or contemplated at the time of its publication, and, although some of his predecessors, like James Thomson, Massieu, Horstmann, had come within sight of the new land and even skirted its shores, Gibbs, with the adventurous spirit of the true pioneer, not only conquered and explored it, but systematically surveyed it, living to see part of his territory occupied by a thriving band of workers, the physical chemists. Cayley, in his report on theoretical dynamics in 1857,[12] expressed his conviction that the science of statics "does not

[9] *Phil. Tr.*, 1865., CLV., 497–501.

[10] "Tagebl. d. Versamml. d. deutsch. Naturf. u. Aerzte 1889," Heidelberg, 1890, 144–9.

[11] *Deutsche Rev.*, 1907, XXXII., Pt. I., 16.

[12] "Report British Association for the Advancement of Science," 1857.

admit of much ulterior development." The work of Gibbs has added to it the immense field of chemical equilibrium and wherever "phases," "heterogeneous systems," "chemical and thermodynamic potentials," or "critical states" are mentioned he has left his impress upon modern scientific thought. It is not without reason then, that Ostwald has called this mathematician "the founder of chemical energetics," asserting that "he has given new form and substance to chemistry for another century at least."[13]

Josiah Willard Gibbs was born in New Haven, Conn., on February 11, 1839. His father, who was descended from Sir Henry Gibbs, of Honington, Warwickshire, was professor of sacred literature in Yale College during the years 1821–61, and was esteemed for unusual scholarship in his day. The son, like many other mathematicians, showed early aptitude for linguistic as well as for mathematical studies, and, entering Yale in 1854, was graduated in 1858, after winning many prizes and distinctions in Latin and mathematics. He began to teach mathematics and physics at Yale in 1863, having received his doctor's degree in that year. During 1866–69 he traveled in Europe, studying his chosen subjects at Paris, Berlin and Heidelberg, and hearing the lectures of Magnus, Kirchhoff and Helmholtz. In July, 1871, two years after his return, he was appointed professor of mathematical physics in Yale College, about the same time that Clerk Maxwell assumed similar duties in the Cavendish Laboratory, at Cambridge. This position Professor Gibbs held until his death, April 28, 1903. Professor Gibbs devoted his whole life to his work, the interests of his university and his pupils, and apart from the earlier years of travel and some excursions into the field of controversy, his was the quiet and uneventful career of the typical man of science. During his period of productive activity, 1873–1902, he made important contributions to the electromagnetic theory of light, multiple algebra and vector analysis, astronomy, theoretical and statistical dynamics, but his enduring fame rests chiefly upon his work in thermodynamics, the science which, in the words of his English biographer, he reduced "to its canonical form." He was a member of most of the important scientific societies of the world, was Rumford medalist of the American Academy of Arts and Sciences in 1881 and in 1901, the Royal Society, of London, conferred its highest distinction, the Copley medal, upon Professor Gibbs, as being "the first to apply the second law of thermodynamics to the exhaustive discussion of the relation between chemical, electrical and thermal energy and capacity for external work."[14]

"The history of thermodynamics," says Maxwell, "has an especial

[13] Am 28. April 1903 verschied im 64. Lebensjahre der Schöpfer der chemischen Energetik, J. Willard Gibbs. Der allgemeinen Chemie hat er für ein Jahrhundert Form und Gehalt gegeben." *Ztschr. f. phys. Chem.*, 1903, XLIII., 760.

[14] *Nature*, London, 1901–2, LXV., 107–8.

interest as the development of a science within a short time and by a small number of men, from the condition of a vague anticipation of nature to that of a science with secure foundations, clear definitions and exact boundaries."[15] Its development falls conveniently into three stages: (1) The derivation of the two laws governing thermal transformations of energy by Carnot, Rankine, Mayer, Joule, Clausius and Kelvin. (2) The deductive application of the second law to all physico-chemical phenomena by Gibbs. (3) The application of probabilities and statistical methods to the kinetic theory of gases by Clausius, Kelvin, Maxwell and Boltzmann and the final derivation of the theorems and equations of thermodynamics by statistical induction from the average behavior of mechanical systems by Gibbs.

"It must not be thought that heat generates motion or motion heat (though in some respects this is true) but the very essence of heat or the substantial self of heat is motion and nothing else.[16] In this sentence from the *Novum Organum* it is clear that Bacon, like Descartes, Count Rumford, Sir Humphry Davy and Young, had a more or less definite notion of the dynamic nature of heat and its convertibility into work. But the exact science which treats of heat as a mode of energy begins with the publication, in 1824, of the "Réflexions sur la puissance motrice du feu" of Sadi Carnot, whom Lord Kelvin calls the "profoundest thinker in thermodynamic philosophy" in the first half of his century.[17] In this little work we have the first treatment of the heat engine as a reversible "cycle of operations," a mechanism which can be worked backward with its every action reversed; and such a system is now known everywhere as a "Carnot cycle." Carnot compared the motor power of heat to a fall of water.[18] As the power of the waterfall depends upon its height and the quantity of fluid employed, so the motor power of heat depends, not upon the nature of the working substance, but upon the quantity of heat employed and the difference in temperature between its source (the boiler) and the sink (or exhaust cylinder) to which it flows. A heat motor, then, requires a hot body and a cold body; the ideally perfect engine would be completely reversible and the efficiency of engines working between the same limits of temperature is the same. In other words, heat can not perform work except by spontaneous flow from a higher to a lower temperature. This is Carnot's principle, from which is derived

[15] *Ibid.*, 1877–8, XVII., 257.

[16] Bacon, "Novum Organum," English translation of 1850, p. 165.

[17] Kelvin, "Popular Lectures," London, 1894, Vol. II., 460.

[18] "On peut comparer la puissance motrice de la chaleur à celle d'une chute d'eau: . . . la puissance motrice d'une chute d'eau dépend de la hauteur et de la quantité du liquide; la puissance motrice de la chaleur dépend aussi de la quantité de calorique employé, et de ce que nous appellerons le hauteur de sa chute, c'est à dire de la différence de température des corps entre lesquels se fait l'échange du calorique." Carnot, "Réflexions," 1824, 15.

the first statement of the second law of thermodynamics, that as water flows towards the sea-level, but never backwards to its source, so *heat can not flow from a colder to a warmer body.* But Carnot, like every one else in his day, still thought that heat (*calorique*), like the water in the waterfall, was an indestructible, material substance and that the quantity of heat given out by the exhaust chamber of the engine is exactly the same as that taken in at the boiler. Although his posthumous papers indicate that he corrected this view before his death, he assumed that if we could find some way to consume the heat of a given body without the necessity of conveying it to a colder body, we might create motor power without fuel or obtain work from nothing, which would be perpetual motion. As late as 1865 an authority like Rankine[19] still believed that heat is of material essence, and when in 1842–7 the labors of Robert Mayer and of Joule established the mechanical equivalent of heat and Helmholtz[20] in 1847 showed that the first law of thermodynamics, the principle of conservation of energy, is applicable to all physical phenomena, it was found difficult to reconcile this principle with Carnot's tacit assumption that heat is unchangeable and indestructible. Even a physicist like William Thomson[21] (the late Lord Kelvin) confessed himself baffled by the problem in 1849 and turned aside to establish his "absolute scale of temperature," without which further progress in the science would have been impossible; but his brother James Thomson, one of the earlier pioneers of physical chemistry, was able, by an implicit denial of Carnot's assumption, to predict and prove that the freezing point of water would be lowered by pressure (1849).[22] The difficulty was, at length, settled in 1850 by Clausius, whose memoir "On the motor power of heat," "marks," says Gibbs, "an epoch in the history of physics," for before its publication, "truth and error were in a confusing state of mixture,"[23] and "wrong answers were confidently urged by the highest authorities."

To Clausius we owe the doctrine, foreshadowed by Bacon, that the heat of a body is the rapid movement, or *vis viva,* of its molecules; the kinetic theory of gases and the molecular theory of electrolysis, since extended by Arrhenius into the doctrine of electrolytic or ionic dissociation. Clausius showed that part of the heat in a Carnot cycle is converted into available mechanical energy and consumed as work, while the rest of the heat can not be so utilized, because it exists in a completely diffused state. The perpetual motion which might be obtained from utilizing the heat of surrounding objects is impossible because such heat being completely diffused is, in Lord Kelvin's phrase, un-

[19] Rankine, *Phil. Mag.*, 1865, 244.

[20] Helmholtz, "Ueber die Erhaltung der Kraft," Berlin, 1847.

[21] Sir W. Thomson, *Tr. Roy. Soc. Edinb.*, 1849, XVI., 543.

[22] J. Thomson, *Ibid.*, 575–80.

[23] Gibbs, *Proc. Am. Acad. Arts and Sci.*, 1888–9, n. s., XVI., 459.

available thermal energy. So the fallacious principle of the conservation of heat became merged into the doctrine of conservation of energy; the reconciliation between the first and second laws, which, like the Kantian antinomies, had seemed mutually contradictory, was effected, and Clausius reasoned that heat can not flow from a colder to a warmer body without compensation, that is, without the intervention of external forces. Meanwhile Lord Kelvin, to whom we owe our ideas and definitions of intrinsic and available energy, was able, in 1852, to shadow forth that comprehensive form of the second law afterwards stated by him as a physical law of irreversibility, according to which there is a universal tendency in nature towards irrevocable dissipation of energy.[24] From this time on progress in the science was rapid. The mathematical part of the theory was improved by the introduction of the scalar value which Rankine called the "thermodynamic function"[25] and Clausius the "entropy"[26] of a body, a variable quantity, momentary increase or decrease of which indicates (in a reversible physico-chemical transformation) whether heat is leaving or entering the body at that moment, irrespective of its temperature or previous condition. The temperature of a body, although measured by arbitrary standards, is in reality a non-measurable "intensity" or quality of the body, depending upon whether it is capable of giving up or receiving heat, *i. e.*, upon its dynamic potentiality; and, in practise, addition of heat to a body may change its physical state but does not necessarily alter its temperature; nor does a change of temperature, as Trevor has recently insisted,[27] necessarily imply absorption or development of heat; but the entropy of a body is a definite measurable "capacity," and has been compared

[24] W. Thomson, *Phil. Mag.*, 1852, IV., 304. "Available energy is energy which we can direct into any required channel. Dissipated energy is energy which we can not lay hold of and direct at pleasure, such as the energy of the confused agitation of molecules which we call heat." Maxwell, *sub voce* "Diffusion."

[25] Rankine, *Phil. Tr.*, 1854, CXLIV., 126.

[26] Clausius, *Poggend. Ann.*, 1855, CXXV., 390.

[27] "When a mass of air is adiabatically compressed or when it expands into a vacuum, the temperature of the mass changes, but no heat is added to it. When heat is added to a block of metal, the temperature of the block rises. When heat is added to a mass of liquid water and overlying water vapor supporting a constant pressure, the temperature of the mass is not altered. Heat may be added to a mixture of potassium sulphocyanate and water in the process of forming a mixture, and the temperature fall. . . . The quantity of 'heat' added to a body in a change of its thermodynamic state is the work absorbed or absorbable by the body through direct intervention of a change of the temperature of another body. This is all that a 'quantity of heat' means. To assume it to mean a quantity of an imponderable fluid, or a quantity of the kinetic energy of hypothetical and inaccessible particles is to replace direct statement of physical facts, made with the aid of clearly defined terms, by a hypothetical interpretation of the facts." J. E. Trevor, *Jour. Phys. Chem.*, 1908, XII., 316.

by Trevor to the weight in a mechanical system. For instance, imagine a frictionless, reversible mechanical system, such as a weight suspended by a cord passing over a pulley, and let this weight by its fall to the ground do a certain amount of work, such as raising a body attached to the other end of the cord. The potential energy of the system is measured by the height of the weight above ground, and when the weight falls, the available energy of the system decreases at each point and moment of the descent, while the unavailable energy undergoes a corresponding increase point for point. On reversing the operation and raising the weight, the available energy of the system is seen to increase while the unavailable energy decreases (*i. e.*, increases in a negative direction). So, in any reversible thermodynamic system, the entropy at any moment is an index, determinant, or coefficient of the relative amount of unavailable energy it possesses. When the temperature in an isolated reversible system is constant, as in jacketed steam, the system is "isothermal" and the entropy may vary at any instant; but if a reversible system be so isolated that no heat can enter or leave the body, the temperature might vary but the entropy would be constant, and such systems, of which we have an approximation in the insulated cylinder of an engine, were called "adiabatic" by Rankine and "isentropic" by Gibbs.

There are no mathematical or ideally reversible systems in existence, although we have natural approximations to them in the motions of the heavenly bodies and in certain chemical reactions, or human approximations in reversible heat engines or reversible electric apparatus; the spontaneous processes of nature are always irreversible, proceeding irrevocably in a definite direction with no negative or reversed dissipation of energy. In spontaneous, irreversible flow of heat from a warmer to a colder body, the entropy or unavailable thermal energy of the system increases inevitably to a maximum. In other words, the entropy of a system is a criterion of its loss of efficiency or available energy during irreversible change, and it follows, in the memorable and aphoristic statement of the first and second laws by Clausius, that, while the energy of the universe is constant, its entropy (or that part of its energy which is unavailable) tends to a maximum and can never decrease:

> **Die Energie der Welt ist constant,**
> **Die Entropie der Welt strebt einem Maximum zu.**

With this important generalization, which is the motto of Gibbs's principal memoir, the first stage of thermodynamics ends. By stating the second law as irreversible increase of entropy in natural processes and by adopting some definite standard of the latter, all exact or scalar relations in thermodynamics can be treated as shown by Rankine, Clausius, and Gibbs, in a precise and definite manner.[28] But the

[28] Maxwell and Tait originally used the term "entropy" as a synonym of

Helmholtz-Kelvin statement of the first and second laws as conservation and dissipation of energy enables us to apply these principles in the broadest and most philosophical way. Lord Kelvin extended the application of the second law to cosmic physics and, with Boltzmann, to predictions as to the ultimate thermal death of the earth. Meanwhile Clausius, Maxwell and Boltzmann began to apply the second law to the kinetic theory of gases, a phase of the subject which belongs essentially to the last stage of its development. Maxwell in particular emphasized the important point that since the heat of a body is the kinetic energy of its molecular motions, the second law is in reality not a mathematical but a statistical truth. It can not, says Maxwell, be reduced to a form as axiomatic as that of the first law, but stands upon a lower plane of probability, because it depends upon the motions of millions of molecules of which we can not get hold of a single one.[29] Could we reduce ourselves to molecular dimensions, and with the gift of molecular vision trace the movements of individual molecules, the distinction between work and heat would

Thomson's "available energy," with the statement that Clausius meant by it that part of the energy which can not be converted into work. As Gibbs pointed out, this is entirely incorrect. The entropy of a body is a definite physical property of the body itself, and can not be measured by the same unit as energy. If dQ represent the amount of heat imparted to a body at any point and T its absolute temperature at that point, Clausius has shown that dQ/T represents the infinitesimal change of entropy at that point for any given moment. The total change of entropy of any reversible chemical system in passing from an initial state a to a final state b would then be

$$\Sigma \int_a^b \frac{dQ}{T},$$

and for a reversible (Carnot) cycle the mathematical statement of the second law is the "Carnot-Clausius equation":

$$\int \left(\frac{dH}{T}\right) = 0.$$

This means that the positive and negative entropies of the system in passing from a to b and in reversing backwards from b to a must balance each other. Or as Gibbs has expressed it, "The second law requires (for a reversible cycle) that the algebraic sum of all the heat received from external bodies, divided, each portion thereof, by the absolute temperature at which it is received shall be zero." The criterion of *irreversible* processes is the "inequality of Clausius"

$$\int \left(\frac{dQ}{T}\right) < 0$$

which implies that the phenomenon will proceed irrevocably or irreversibly in a definite direction, entropy increasing or available energy dissipating to a maximum until a final state of rest or equilibrium (uniformly distributed temperature) is attained. Reversible thermodynamics deals, then, with equations; irreversible thermodynamics with inequalities, because in reversible processes the total entropy of a system remains unchanged while in irreversible processes it continually increases.

[29] Maxwell, *Nature*, London, 1877–8, XVII., 279.

vanish, and nothing would remain but the motions of material systems and the laws of mechanics. Hence the second law must either be obtained from our actual experience "with real bodies of sensible magnitude," or else derived *a posteriori*, as shown by Boltzmann, Helmholtz and Gibbs, from averages of the hypothetical motions of mechanical systems. In aid of this conception of the problem, Maxwell introduced his whimsical notion of the "sorting demon," a being endowed with molecular vision, who would be able through intelligence alone to sort or direct the molecular movements at will and so reverse the action of the second law on occasion.[30]

The second stage of thermodynamics begins in 1872–3 with August Friedrich Horstmann's application of the entropy principle to problems of chemical dissociation.[31] In October, 1873, Horstmann announced the condition for chemical equilibrium to be that of maximum entropy,[32] and in December of the same year Gibbs, in a modest foot-note, stated that the condition for thermodynamic equilibrium in a chemical system at constant temperature and pressure is that the function now universally known as the thermodynamic potential should be a minimum.[33] In 1875 Lord Rayleigh stated that dissipation of energy is a sufficient if not a necessary condition for chemical change,[34] and in October, 1875, appeared the first installment of Gibbs's memoir of three hundred pages on chemical equilibrium, which, by its applications of the entropy principle to all physico-chemical or energetic phenomena, has become a true scientific classic doing for the second law what Helmholtz, in his treatise on the conservation of energy, had previously done for the first.

Gibbs began his work in thermodynamics in 1873, with two important papers on diagrams and surfaces.[35] In the first of these he made a careful and thoroughgoing study of all the diagrams that might be of use or value in thermodynamics, the best known being that upon which volume and pressure are erected to scale as coordinates, derived from the familiar Watts' indicator diagram found upon every steam engine. Of the new diagrams which Gibbs introduced, he attached most importance to the volume-entropy diagram, because it tells more about the physical properties of a working substance than about the heat employed or the work done. But the most important of Gibbs's innovations for practical engineering purposes is the temperature-

[30] For a description of the Maxwell demon and the powers ascribed to him see Lord Kelvin's paper in *Nature*, 1879, 126.

[31] Horstmann, *Ann. d. Chem. u. Pharm.*, 1872, 8. Suppl.-Bd., 112–33.

[32] Horstmann, *Ibid.*, 1873, CLXX., 192–210.

[33] Gibbs, *Tr. Connect. Acad.*, Dec., 1873, II., foot-note to p. 393.

[34] Lord Rayleigh, *Proc. Roy. Inst.*, 1875, VII., 388.

[35] *Tr. Connect. Acad.*, 1873, II., 309–42, 382–404. Translated into French as "Diagrammes et surfaces thermodynamiques," Paris, C. Naud, 1903. Translated into German by Ostwald in 1892.

entropy diagram, which represents the efficiency of a Carnot cycle as a simple rectangular figure and is, he points out, "nothing more nor less than a geometrical representation of the second law of thermodynamics." The area of the Watts diagram represents the work done by the engine; the area of the Gibbs diagram represents the heat it has received and, either upon separate blackboards or upon "quadrant diagrams," the two taken together have proved invaluable in teaching thermodynamics to engineers. As the indicator diagram tells the engineer what he wants to know about the work done upon the piston, the efficiency of the valves and passages and the total horse power of the engine, the entropy diagram gives him the heat taken in or given out and shows directly the losses of efficiency from such heat wastes as wire-drawing of steam, incomplete expansion, etc. Professor John Perry says that the thermodynamics of heat engines is revealed by the entropy diagram "as it can be revealed in no other way," and he describes how "a man almost illiterate, innocent of algebra, can use his t, ϕ diagram of water steam or air or ammonium anhydride, obtaining in a few minutes answers to problems which the mathematical engineers of years ago spent days in solving."[36] In England the temperature-entropy diagram has been found very useful in "engine testing laboratories," and its ultimate adoption is due to the persistent crusade of Mr. Macfarlane Gray, late chief engineer of the Royal Navy, who introduced it independently in 1880 as the "theta-phi" (θ, ϕ) diagram. American engineers should not forget that this diagram was first described in scientific literature by Professor Willard Gibbs,[37] who clearly pointed out its advantages, in visualizing the second law, for teaching purposes and its use and significance when attached to heat-engines. In his second memoir[38] Gibbs extends his graphical methods to three-dimensional space, the first example of which was the volume-pressure-temperature diagram employed by James Thomson[39] in 1871. The first solid diagram described by Gibbs had for its coordinates, volume, entropy and energy and is now generally known as the "thermodynamic surface." It is a solid model or relief-map, affording a bird's-eye view of the chemico-physical changes of a system at constant temperature and pressure as it passes through the coexistent states of solid, liquid, vapor or gas. Maxwell, who had himself written learn-

[36] *Nature*, London, 1902–3, LXVII., 604.

[37] Gibbs, *Tr. Connect. Acad.*, April, 1873, II., 317–25. The equivalent of an entropy diagram was laid down and described by the Belgian physicist M. Belpaire in 1872 (*Bull. Acad. roy. d. sc., Brux.*, 1872, 2. s., XXXIV., 520–6), but his treatment of the matter is so sketchy and slight in comparison with the exhaustive and illuminative handling of Gibbs that it seems negligible. The mere plotting of the diagram itself is nothing, for it was for years implicit in Rankine's algebraic use of the "thermodynamic function" (ϕ) as a coordinate (1854), and to this day the British unit of entropy is called a "Rank."

[38] *Tr. Connect. Acad.*, 1873, II., 382–404.

[39] J. Thomson, *Proc. Roy. Soc. Lond.*, 1871, XX., 1.

edly of diagrams, immediately recognized the importance of this paper, part of which he incorporated as a chapter in his "Theory of Heat,"[40] and, shortly before his death, he sent Gibbs a copy of a model of the thermodynamic surface constructed to scale with his own hands.[41] These solid diagrams have played a great part in the elaborate studies of the continuity of gaseous and liquid states by Van der Waals and his pupils, of which we have recently witnessed the final triumph in the liquefaction of helium.

During the years 1875–8, Gibbs published the work which is his chief title to fame, his memoir "On the Equilibrium of Heterogeneous Substances."[42] This treatise deals, as the title implies, with the statics of chemical substances which, as gases, vapors, liquids or solids, are in actual physical contact with each other, whether influenced or modified by gravity, osmosis, catalysis, capillarity or electromotive force or existing under such varied aspects as gaseous mixtures, liquid films, "solid solutions," or crystals. For the first time chemical substances are treated as continuous or contiguous "phases" of "matter in mass" acted upon, like mechanical systems, by forces having "potentials"—a new way of looking at things which has since become the definite view-point of physical chemistry. As Larmor says, "Gibbs made a clean sweep of the subject, and workers in the modern experimental science of physical chemistry have returned to it again and again to find their empirical principles forecasted in the light of pure theory, and to derive fresh inspiration for new departures."[43] Some of its theorems, as the Helmholtz doctrine of free energy,[44] Konowalow's theorem of indifferent points,[45] Curie's theory of "crystal habit,"[46] were rediscovered by later investigators in ignorance of the earlier work. Indeed the primary intention of Gibbs's memoir, to treat chemical changes as a branch of mechanics, was not, at first, clearly understood, the long deferred review in the "Fortschritte der Physik"[47] merely listing its contents. Maxwell, however, with the same cordial recognition which he had shown to Rowland, grasped its significance at once, incorporated some of its results in his memoir on "Diffusion,"[48] and in an appreciative discourse before the Cambridge Philo-

[40] Maxwell, "Theory of Heat," London, 1902, 204–8.

[41] "Copies of this model were distributed by Maxwell evidently with a certain amount of playful mystery, for each recipient thought that he was the happy possessor of one of (at most) three. The writer knows of six at least, and possibly there are more." C. G. K. in *Nature*, 1907, LXXXV., 361.

[42] Tr. *Connect. Acad.*, 1875–8, III., 108–248; 343–594. Abstract by Gibbs in *Am. J. Sc.*, 1878, 3. s., XVI., 441–458.

[43] Larmor, "Encycl. Britan.," 10th ed., 1902, IV., 172.

[44] Helmholtz, *Sitzungsb. d. k. preuss. Akad. d. Wissensch.*, XXII.

[45] Konowalow, *Wied. Ann.*, 1881, XIV., 48.

[46] Curie, *Bull. Soc. Min.*, 1885, VIII., 145.

[47] *Fortschr. d. Physik.*, 1878, XXXIV., 198.

[48] "Encycl. Britan.," 9th ed., VII., 214–21.

sophical Society in 1876 declared that the methods of Gibbs "seemed to throw a new light upon thermodynamics." Copies of the work were consequently much prized and sought after in England about this time; but the most substantial recognition of Gibbs's work was to come from Holland, where a long line of physical chemists, van der Waals, Roozeboom, van't Hoff, Lorentz, Schreinemakers, Stortenbeker, van Laar, Hoitsema, Kamerlingh Onnes, have developed his ideas with very substantial additions to their own fame. Parallel with the work of these men and the development of the important laws of Goldberg and Waage, van't Hoff and Arrhenius, the science of physical chemistry, which DuBois Reymond called "the chemistry of the future," came into being under the leadership of Ostwald in Germany and (since 1896) of Professor Bancroft in America. With the gradual recognition of the significance of "reversible reactions"[49] and of Sainte-Claire-Deville's doctrine of chemical dissociation, the algebraic formulæ of Gibbs became slowly converted into working theories of physical chemistry. In 1892 Ostwald translated Gibbs's papers as "Thermodynamische Studien" and part of them were rendered into French in 1899 by Le Chatellier. The purely mathematical part of Gibbs's theory has been developed in extension by the labors of Duhem, Paul Sorel, Trevor, Bancroft, van der Waals, Larmor and Bryan. Roozeboom, van der Waals and Bancroft have made the widest applications of his ideas to chemistry, while their best interpretation from the dynamic or energetic point of view is that of Ostwald[50] and of Larmor.[51] Although a genial and engaging writer in his discourse on "Multiple Algebra" and his biographical sketches, the strictly scientific papers of Gibbs are not, like those of Maxwell, Boltzmann and Hertz, attractive reading. Indeed, it has been said of his memoir on equilibrium that Ostwald is one of the few people in the world who ever read every word of it, for the student is repelled, not so much by its bristling quickset of some seven hundred formulæ as by the severe and austere reasoning and a literary style that is swift in movement and (doubtless from the very nature of the subject matter) tense and dry in quality. Although endowed with the scientific imagination of a man of genius, Gibbs's strong point in demonstration was unusual quickness of intelligence

[49] The difference between reversible and irreversible chemical processes could hardly be better indicated than in the following comparison of van't Hoff: "Kill a chicken and prepare chicken soup; it would then be very difficult to get your chicken again. This is because preparing chicken soup is not reversible. On the contrary, let water evaporate or freeze, it will be easy to reproduce the water" (*J. Phys. Chem.*, 1905, IX., 87). The distinction between reversible and irreversible reactions is thus a physico-chemical or thermodynamic conception, depending, like the operations of mechanical systems, upon the initial conditions, under which the phenomenon takes place.

[50] See Ostwald, "Lehrb. d. allg. Chemie," Leipzig, 1896, II., 2. Th., 114–5.

[51] See "Encycl. Britan.," 10th ed., XXVIII., *sub voce* Energetics.

and great capacity for the rigors of formal logic, and the rapid movement of his mind as he clears away the underbrush and covers the vast area of his new territory is wearying and even confusing to the reader. The intention of the present résumé is frankly journalistic, aiming only to emphasize such points in the Gibbsian theory as have been thrown into strongest relief by their relation to recent science. These are:

The General Equation of Thermodynamics.—In applying the laws of dynamics to thermal phenomena, Clausius had shown that if we differentiate with respect to the volume of a body, we obtain its pressure with reversed sign; if we differentiate with respect to its entropy we obtain its temperature on the thermodynamic scale; the energy of the body can then be expressed as a function of its volume and entropy, the differential coefficients with respect to the latter being the pressure (with negative sign) and the temperature. Gibbs has extended these principles to the formulation of a fundamental equation of thermodynamics, in which the new departure is taken of introducing the masses of the chemical components of a system as variables, the differential coefficients in this case being certain new conceptions which he terms the "potentials" of the substances considered. From this equation most of the principles and formulæ of thermodynamics can be deduced. It lies at the basis of the new aggregate of sciences called "energetics"[52] as well as of mathematical chemistry, in which all spontaneous changes of substance or state are regarded as more or less direct consequences of the second law. The equations of Clausius and Gibbs, although exceedingly general and difficult of application to chemistry, are exact, representing the physical facts.[53]

The Chemical Potentials.—In the fundamental equation of Gibbs we distinguish two classes of variables, of which the volume, entropy and masses of the component substances are looked upon as magnitudes or *capacities,* while the temperature, the pressure and the potentials are to be thought of as qualitative, being non-measurable, non-additive physical *intensities* of the system considered. Thus the pres-

[52] Thoughout this paper, "energetics," thermodynamics and physical chemistry are regarded as practically identical in scope, in the original sense in which Gibbs referred to all material systems as "actually thermodynamic," or Ostwald to "das glänzendste Gebiet der heutigen Physik und Chemie, die reine Thermodynamik, oder da dieser Name viel zu eng ist, die reine Energetik."

[53] If ϵ, t, η, p and v represent the energy, temperature, entropy, pressure and volume of a homogeneous substance respectively, the equation of Clausius may be written $d\epsilon = td\eta - pdv$. It is applicable to all one-component systems, such as steam in a boiler. The equation of Gibbs, which is applicable to any chemical system whatever, is written

$$d\epsilon = td\eta - pdv + \mu_1 dm_1 + \mu_2 dm_2 \cdots + \mu_n dm_n,$$

where μ_1, μ_2 $\cdots$ denote the chemical potentials, and m_1, m_2 $\cdots$ the masses of the chemical components of the system.

sure of a substance connotes the intensity with which it tends to expand, its temperature the intensity with which it tends to part with heat, while the potential of a given chemical component represents (in Maxwell's acute interpretation) the intensity with which it tends to expel itself from the mass or compound containing it.[54] Mathematically the Gibbsian potential, which Maxwell thought "likely to become very important in the history of chemistry," has been identified by Larmor with the marginal available energy per unit mass of substance at constant temperature,[55] depending upon the percentage composition of the substance rather than its actual quantity. The chemical potentials may be regarded, not unlike the potentialities of an individual, as definite intensities which set things going, and as such their close relationship to the surface energies and surface tensions of biological science is obvious. As to the ultimate nature of the forces bound up with these potentials, whether due in the last analysis to electronic stresses or rotational stresses in the ether simply, we know little or nothing. Thermodynamic (or "energetic") doctrine rests upon the simple idea that mechanical, thermal, chemical and electric forces are different modes of energy, continually changing and passing into one another in an apparently elusive way, and is more concerned with their dynamic effects than with their actual nature.

(*To be continued*)

[54] See the report of Maxwell's lecture in *Am. J. Sc.*, 1877, 3. s., XIII., 380, which is fuller than the one given in his collected writings.

[55] "Encycl. Britan.," 10th ed., XXVIII., 168.

ON A VERY PREVALENT ABUSE OF ABSTRACTION

By Professor WILLIAM JAMES

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ABSTRACT concepts, such as elasticity, voluminousness, disconnectedness, are salient aspects of our concrete experiences which we find it useful to single out. Useful, because we are then reminded of other things that offer those same aspects; and, if the aspects carry consequences in those other things, we can return to our first things expecting those same consequences to accrue.

To be helped to anticipate consequences is always a gain, and, such being the help that abstract concepts give us, it is obvious that their use is fulfilled only when we get back again into concrete particulars by their means, bearing the consequences in our minds, and enriching our notion of the original objects therewithal.

Without abstract concepts to handle our perceptual particulars by, we are like men hopping on one foot. Using concepts along with the particulars, we become bipedal. We throw our concept forward, get a foothold on the consequence, hitch our line to this, and draw our percept up, traveling thus with a hop, skip and jump over the surface of life at a vastly rapider rate than if we merely waded through the thickness of the particulars as accident rained them down upon our heads. Animals have to do this, but men raise their heads higher and breathe freely in the upper conceptual air.

The enormous esteem professed by all philosophers for the conceptual form of consciousness is easy to understand. From Plato's time downwards it has been held to be our sole avenue to essential truth. Concepts are universal, changeless, pure; their relations are eternal; they are spiritual, while the concrete particulars which they enable us to handle are corrupted by the flesh. They are precious in themselves, then, apart from their original use, and confer new dignity upon our life.

One can find no fault with this way of feeling about concepts so long as their original function does not get swallowed up in the admiration and lost. That function is of course to enlarge mentally our momentary experiences by adding to them the consequences conceived; but unfortunately that function is not only too often forgotten by philosophers in their reasonings, but is often converted into its exact opposite, and made a means of diminishing the original experience by denying (implicitly or explicitly) all its features save the one specially abstracted to conceive it by.

This itself is a highly abstract way of stating my complaint, and it needs to be redeemed from obscurity by showing instances of what is meant. Certain particular beliefs dear to my heart have been conceived in this viciously abstract way by critics. One is the "will to believe," so-called; another is the indeterminism of certain futures; a third is the notion that truth may vary with the standpoint of the man who holds it. I believe that the perverse abuse of the abstracting function has often led critics to employ false arguments against these doctrines, and has led their readers too to false conclusions. I should like to try to save the situation, if possible, by a few counter-critical remarks.

Let me give the name of "vicious abstractionism" to a way of using concepts which may be thus described: We conceive a concrete situation by singling out some salient or important feature in it, and classing it under that; then, instead of adding to its previous characters all the positive consequences which the new way of conceiving it may bring, we proceed to use our concept privatively; we reduce the originally rich phenomenon to the naked suggestions of that name abstractly taken, treating it as a case of "nothing but" that concept, and acting as if all the other characters from out of which the concept is abstracted were expunged.[1] Abstraction, functioning in this way, becomes a means of arrest far more than a means of advance in thought. It mutilates things; it creates difficulties and finds impossibilities; and more than half the trouble that metaphysicians and logicians give themselves over the paradoxes and dialectic puzzles of the universe may, I am convinced, be traced to this relatively simple source. *The viciously privative employment of abstract characters and class-names* is, I am persuaded, the original sin of the metaphysical mind.

To proceed immediately to concrete examples, cast a glance at the belief in "free will," demolished with such specious persuasiveness in this magazine not long ago by the skilful hand of Professor Fullerton.[2] When a common man says that his will is free, what does he mean? He means that there are situations of bifurcation inside of his life in which two futures seem to him equally possible, for both have their roots equally planted in his present and his past. Either, if realized, will grow out of his previous motives, character and circumstances, and will continue uninterruptedly the pulsations of his personal life. But sometimes both at once are incompatible with physical nature, and then it seems to the naïve observer as if he made a choice between them *now*, and that the question of *which future is to*

[1] Let not the reader confound the fallacy here described with legitimately negative inferences such as those drawn in the mood "Celarent" of the logic-books.

[2] POPULAR SCIENCE MONTHLY, Vols. 58 and 59.

be, instead of having been decided at the foundation of the world, were decided afresh at every passing moment in which fact seems livingly to grow, and possibility to turn itself towards fact.

He who takes things at their face-value here may indeed be deceived. He may far too often mistake his private ignorance of what is predetermined for a real indetermination of what is to be. Yet, however imaginary it may be, his picture of the situation offers no appearance of breach between the past and future. A train is the same train, its passengers are the same passengers, its momentum is the same momentum, no matter which way the switch which fixes its direction is placed. For the indeterminist there is at all times enough past for all the different futures in sight, and more besides, to find their reasons in it, and whichever future comes will slide out of that past as easily as the train slides by the switch. The world, in short, is just as *continuous with itself* for the believers in free will as for the rigorous determinists, only the latter are unable to believe in points of bifurcation as spots of really indifferent equilibrium or as containing shunts which there—and there only, not before—direct existing motions without altering their amount.

Were there such spots of indifference, the rigorous determinists think, the future and the past would be separated absolutely, for, *abstractly taken, the word "indifferent" suggests disconnection solely.* Whatever is indifferent is in so far forth unrelated and detached. Take the term thus strictly, and you see, they tell us, that if any spot of indifference is found upon the broad highway between the past and the future, then *no* connection of any sort whatever, no continuous momentum, no common aim or agent, can be found on both sides of the gaping wound which it makes.

Mr. Fullerton writes—the italics are mine—as follows:

> In so far as my action is free, what I have been, what I am, what I have always done or striven to do, what I most earnestly wish or resolve to do at the present moment—these things can have *no more to do with its future realization than if they had no existence.* . . . The possibility is a hideous one; and surely even the most ardent free-willist will, when he contemplates it frankly, excuse me for hoping that if I am free I am at least not very free, and that I may reasonably expect to find *some* degree of consistency in my life and actions. . . . Suppose that I have given a dollar to a blind beggar. Can *I,* if it is really an act of free will, be properly said to have given the money? Was it given because I was a man of tender heart, etc., etc.? . . . What has all this to do with acts of free-will? If they are free, they must not be conditioned by antecedent circumstances of *any* sort, by the misery of the beggar, by the pity in the heart of the passer-by. They must be causeless, not determined. They must drop from a clear sky out of the void, for just in so far as they can be accounted for, they are not free.[1]

Heaven forbid that I should get entangled here in a controversy about the rights and wrongs of the free-will question at large, for I

[1] *Loc. cit.,* Vol. 58, pp. 189, 188.

am only trying to illustrate vicious abstractionism by the conduct of some of the doctrine's assailants. The moments of bifurcation, as the indeterminist seems to himself to experience them, are moments both of direction and of continuation. But because the direction of growth is not unequivocal, and because in the "either—or" we hesitate, the determinist abstracts this little element of discontinuity from the superabundant continuities of the experience, and cancels in its behalf all the continuously connective characters with which the latter is filled. Choice, for him, means henceforward *dis*connection pure and simple, and a life of choices undetermined to advance *in any respect whatever*, must be a raving chaos, at no two moments of which could we be treated as one and the same man. If Nero were "free" at the moment of ordering his mother's murder, Mr. McTaggart[4] assures us that no one would have the right at any other moment to call him a bad man.

A polemic author ought not merely to destroy his victim. He ought to try a bit to make him feel his error—perhaps not enough to convert him, but enough to give him a bad conscience and to weaken the energy of his defense. These violent caricatures of men's serious beliefs arouse only contempt for the incapacity of their authors to see the concrete situations out of which the problems grow. To treat the negative character of one abstracted element as annulling all the positive features with which it coexists, is not the way to change any actual indeterminist's way of looking on the matter, though it may easily make a prejudiced gallery applaud.

Turn now to some criticisms of the "Will to believe," as another example of the vicious way in which abstraction is currently employed. The right to believe in things for the truth of which complete objective proof is yet lacking is defended by those who apprehend certain human situations in their concreteness. In those situations the mind has alternatives before it, so vast that the full evidence for either brand is missing, and yet so significant that simply to wait for proof, and to doubt while waiting, might often in practical respects be the same thing as weighing down the negative side. Is life worth while at all? Is there any general meaning in all this cosmic weather? Is anything being permanently bought by all this suffering? Is there perhaps a transmundane experience, something in Being corresponding to a "fourth dimension," which, if we had access to it, might patch up some of this world's *zerrissenheit* and make things look more rational than they at first appear? Is there a superhuman consciousness of which our minds are parts, and from which inspiration and help may come? Such are the questions in which the right to take sides for yes or no is affirmed by some of us, while others hold that this is methodologically inadmissible, and summon us to die professing ignorance and proclaiming the duty of every one to refuse to believe.

[4] "Some Dogmas of Religion," p. 179.

I say nothing of the personal inconsistency of some of these critics whose printed works furnish exquisite illustrations of the will to believe, in spite of their denunciations of it as a phrase and as a recommended thing. Mr. McTaggart, whom I will once more take as an example, is sure that "reality is rational and righteous" and "destined *sub specie temporis* to become perfectly good"; and his calling this belief a result of necessary logic has surely never deceived any reader as to its real genesis in the gifted author's mind. Mankind is made on too uniform a pattern for any of us to escape successfully from acts of faith. We have a lively vision of what a certain view of the universe would mean for us. We kindle or we shudder at the thought, and our feeling runs through our whole logical nature and animates its workings. It *can't* be that, we feel, it *must* be this. It must be what it *ought* to be, and it *ought* to be this; and then we seek for every reason, good or bad, to make this which so deeply ought to be, seem objectively the probable thing. We show the arguments against it to be insufficient, so that it *may* be true; we represent its appeal to be to our whole nature's loyalty and not to any emaciated faculty of syllogistic proof. We reinforce it by remembering the enlargement of our world by music, by thinking of the promises of sunsets and the impulses from vernal woods. And the essence of the whole experience, when the individual swept through it says finally "I believe," is the intense concreteness of his vision, the individuality of the hypothesis before him, and the complexity of the various motives and perceptions that issue in his final state.

But see now how the abstractionist treats this rich and intricate vision that a certain state of things must be true. He accuses the believer of reasoning by the following syllogism:

All good desires must be fulfilled;

The desire to believe this proposition is a good desire;

Ergo, this proposition must be believed.

He substitutes this abstraction for the concrete state of mind of the believer, pins the naked absurdity of it upon him, and easily proves that any one who defends him must be the greatest fool on earth. As if any real believer ever thought in this preposterous way, or as if any defender of the legitimacy of men's concrete ways of concluding ever used the general premise "All desires must be fulfilled"! Nevertheless Mr. McTaggart solemnly and laboriously refutes the syllogism in sections 47 to 57 of his very readable book. He shows that there is no fixed rational link, no link in the dictionary, between the abstract concepts "desire," "goodness" and "reality"; and he ignores all the singular links which in the concrete case the believer feels and perceives. He says:

> When the reality of a thing is uncertain, the argument encourages us to suppose that our approval of a thing can determine its reality. And when

this unhallowed link has once been established, retribution overtakes us. For when the reality of the thing is independently certain, we [then] have to admit that the reality of the thing should determine our approval of that thing. I find it difficult to imagine a more degraded position.

Mr. McTaggart ends his chapter with the heroic words:

For those who do not pray, there remains the resolve that, so far as their strength may permit, neither the pains of death nor the pains of life shall drive them to any comfort in that which they hold to be false, or drive them from any comfort [discomfort?] in that which they hold to be true.

How can so ingenious-minded a writer fail to see how far over the heads of the enemy all his arrows pass? When Mr. McTaggart himself believes that the universe is run by the dialectic energy of the absolute idea, his insistent desire to have a world of that sort is felt by him to be no chance example of desire in general, but an altogether peculiar insight-giving passion to which, in this if in no other instance, he would be stupid not to yield. He obeys its concrete singularity, not the bare abstract feature in it of being a "desire." His situation is as particular as that of an actress who resolves that it is best for her to marry and leave the stage, of a priest who becomes secular, of a politician who abandons public life. What sensible man would seek to refute the concrete decisions of such persons by tracing them to abstract premises, such as that "all actresses must marry," "all clergymen must be laymen," "all politicians should resign their posts"? Yet this type of refutation, absolutely unavailing though it be for purposes of conversion, is spread by Mr. McTaggart through many pages of his book. For the aboundingness of our real reasons he substitutes one narrow point. For men's real probabilities he gives an abstraction which no man is tempted to believe.

The abstraction in my next example is less simple, but is quite as flimsy as a weapon of attack. Empiricists think that truth in general is distilled from single men's ideas; and the so-called pragmatists "go them one better" by trying to define what it consists in when it comes. It consists in such a working, I have elsewhere said, on the part of the ideas, as may bring the man into satisfactory relations with objects to which these latter point. The working is of course a concrete working in the actual experience of human beings, among their ideas, feelings, perceptions, beliefs and acts, as well as among the physical things of their environment, and the relations must be understood as being possible as well as actual. In the chapter on truth of my recent book called "Pragmatism"[5] I have myself taken considerable pains to defend this view. Strange have been some of the misconceptions of it by its enemies, and many have these latter been. Among the most formidable-sounding onslaughts on the attempt to introduce some concreteness into our notion of what the truth of an idea may mean,

[5] Longmans, Green & Co., 1908.

is one that has been raised in many quarters to the effect that to make truth grow in any way out of human opinion is but to reproduce that protagorean doctrine that the individual man is "the measure of all things," which Plato in his immortal dialogue, the Thæatetus, laid away so comfortably in its grave two thousand years ago. The two cleverest brandishers of this objection to make truth concrete, Professors Rickert and Münsterberg, write in German, and "Relativismus" is the name they give to the heresy which they endeavor to uproot.

The first step in their campaign against "Relativismus" is entirely in the air. They accuse relativists—and we pragmatists are typical relativists—of being debarred by their self-adopted principles, not only from the privilege which rationalist philosophers enjoy, of believing that these principles of their own are truth impersonal and absolute, but even of framing the abstract notion of such a truth, in the pragmatic sense of an ideal opinion in which all men might agree, and which no man should ever wish to change. Both charges fall wide of their mark. I myself, as a pragmatist, believe in my own account of truth as firmly as any rationalist can possibly believe in his. And I believe in it for the very reason that I *have* the idea of truth which my learned adversaries contend that no pragmatist can frame. I expect, namely, that the more fully men discuss and test my account, the more they will agree that it *fits,* and the less will they desire a change. I may of course be premature in this confidence, and the glory of being truth final and absolute may fall upon some later revision and correction of my scheme, which scheme will then be judged untrue in just the measure in which it departs from that finally satisfactory formulation. To admit, as we pragmatists do, that we are liable to correction (even though we may not expect it) *involves* the use on our part of an ideal standard. Rationalists themselves are, as modest individuals, sceptical enough to admit the abstract possibility of their own present opinions being corrigible and revisable to some degree, so that the fact that the mere *notion* of an absolute standard should seem to them so important a thing to claim for themselves and to deny to us is not easy to explain. If, along with the notion of the standard, they could also claim its exclusive warrant for their own fulminations now, it would be important to them indeed. But absolutists like Rickert freely admit the sterility of the notion, even in their own hands. Truth is what we *ought* to believe, they say, even though no man ever did or shall believe it, and even though we have no way of getting at it save by the usual empirical processes of testing our opinions by one another and by facts. Pragmatically, then, this part of the dispute is idle. No relativist who ever actually walked the earth[6] has denied the constitutive character in his own thinking of the notion of absolute truth. What is challenged by relativists is

the pretence on any one's part to have found for certain at any given moment what the shape of that truth is. Since the better absolutists agree in this, admitting that the proposition "There *is* absolute truth" is the only absolute truth of which we can be sure,[7] further debate is practically unimportant, so we may pass to their next charge.

It is in this charge that the vicious abstractionism becomes most apparent. The anti-pragmatist, in postulating absolute truth, refuses to give any account of what the words may mean. For him they form a self-explanatory term. The pragmatist, on the contrary, articulately defines their meaning. Truth absolute, he says, means an ideal set of formulations towards which all opinions may in the long run of experience be expected to converge. In this definition of absolute truth he not only postulates that there is a tendency to such convergence of opinions, but he postulates the other factors of his definition equally, borrowing them by anticipation from the true conclusions expected to be reached. He postulates the existence of opinions, he postulates the experience that will sift them, and the consistency which that experience will show. He justifies himself in these assumptions by saying that human opinion has already reached a pretty stable equilibrium regarding them, and that if its future development fails to alter them, the definition itself, with all its terms included, will be part of the very absolute truth which it defines. The hypothesis will, in short, have worked successfully all round the circle and proved self-corroborative, and the circle will be closed.

The anti-pragmatist, however, immediately falls foul of the word "opinion" here, abstracts it from the universe of life, and uses it as a bare dictionary-substantive, to deny the rest of the assumptions with which it coexists. The dictionary says that an opinion is "what some one thinks or believes." This leaves every one's opinion free to be autogenous, or unrelated either to what any one else may think, or to what the truth may be. Therefore, continue our abstractionists, we must conceive it *as essentially thus unrelated,* so that even were a billion men to sport the same opinion, and only one man to differ, we could admit no collateral circumstances which might presumptively make it more probable that he, not they, should be wrong. Truth, they say, follows not the counting of noses, nor is it only another name for a

[6] Of course the bugaboo creature called "the sceptic" in the logic-books, who dogmatically makes the statement that no statement, not even the one he now makes, is true, is a mere mechanical toy-target for the rationalist shooting gallery—hit him and he turns a summersault—yet he is the only sort of relativist whom my colleagues appear able to imagine to exist.

[7] Compare Rickert's "Gegenstand der Erkentniss," pp. 137, 138. Münsterberg's version of this first truth is that "Es gibt eine Welt"—see his "Philosophie der Werte," pp. 38 and 74. And, after all, both these philosophers confess in the end that the primal truth of which they consider our supposed denial so irrational is not properly an insight at all but a dogma adopted by the will which any one who turns his back on duty may disregard!

majority vote. It is a relation, that antedates experience, between our opinions and an independent something which the pragmatist account ignores, a relation which, though the opinions of individuals should to all eternity deny it, would still remain to qualify them as false. To talk of opinions without referring to this independent something, the anti-pragmatist assures us, is to play Hamlet with Hamlet's part left out.

But when the pragmatist speaks of opinions, does he mean any such insulated and unmotived abstractions as are here supposed? Of course not, he means men's opinions in the flesh, as they have really formed themselves, opinions surrounded by their causes and the influences they obey and exert, and along with the whole environment of social communication of which they are a part. The "experience" which the pragmatic definition postulates *is* the independent something which the anti-pragmatist accuses him of ignoring. Already have men grown unanimous in the opinion that such experience is "of" an independent reality, the existence of which all opinions must acknowledge, in order to be true. Already do they agree that in the long run it is useless to resist experience's pressure; that the more of it a man has, the better position he stands in, in respect of truth; that some men, having had more experience, are therefore better authorities than others; that some are also wiser by nature and better able to interpret the experience they have had; that it is the part of wisdom to compare notes, to discuss, and to follow the opinion of our betters; and that the more systematically and thoroughly the comparison and weighing of opinions is pursued, the truer the opinions that survive are likely to be. *When the pragmatist talks of opinions, it is opinions as they thus concretely and livingly and interactingly and correlatively exist that he has in mind;* and when the anti-pragmatist tries to floor him because the word opinion can also be taken abstractly and as if it had no environment, he simply ignores the soil out of which the whole discussion grows. His weapons cut the air and strike no blow. No one gets wounded in the war against caricatures of belief and skeletons of opinion of which the German onslaughts upon "Relativismus" consist. Refuse to use the word opinion abstractly, keep it in its real environment, and the withers of pragmatism remain unwrung.

That men do exist who are "opinionated," in the sense that their opinions are self-willed, is unfortunately a fact that must be admitted, no matter what one's notion of truth in general may be. But that this fact makes it impossible for truth to form itself authentically out of the life of "opinion," is what no critic has yet proved. Truth may well consist of certain opinions, and does indeed consist of nothing but opinions, though not every opinion need be true. No pragmatist needs to dogmatize about the consensus of opinion in the future being right—he need only *postulate* that it will probably contain more of truth than any one's opinion now.

THE CLOSING OF A FAMOUS ASTRONOMICAL PROBLEM

By Professor W. W. CAMPBELL
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THERE is perhaps no more striking illustration of the power of scientific method than that relating to the discovery of Neptune in 1846. The planet Uranus, until then the outermost known member of our solar system, refused to follow the path computed for it by mathematical astronomers. With the progress of time the discrepancies between its predicted and observed positions grew constantly larger until, in the early eighteen-forties, the discordance amounted to fully 75 seconds of arc. This is a small angle—not more than one twenty-fifth the angular diameter of our moon—yet a very large angle to refined astronomy, for a discrepancy of two seconds would have been detected with ease. The opinion gradually developed that Uranus was drawn from its natural course by the attractions of an undiscovered planet still farther from the sun than itself. Adams in 1843 and Le Verrier in 1845, independently, and each without knowledge of the other's plans, attacked the then extremely difficult problem of determining the approximate orbit, mass and position of an undiscovered body whose attractions should produce the perturbations observed. Regrettable and avoidable delays occurred in searching for the planet after Adams's results were communicated to the astronomer royal, in October, 1845. Le Verrier's results were communicated to the Berlin Observatory in September, 1846, with the request that a search be made. The disturbing planet, later named Neptune, was found on the first evening that it was looked for, less than one degree of arc from the position assigned by Le Verrier. If an energetic search had been made in England the year before, the planet would have been discovered within two degrees of the position assigned by Adams.

The above résumé of this unsurpassed achievement of the human mind forms a natural prelude to the present article, as it was the immediate forerunner of another problem, famous for half a century, which has now been brought to a satisfactory conclusion.

The determination of the orbit of the planet Mercury gave great difficulty to its investigators, principally from two causes:

1. Being the innermost known planet in our system, remaining always near the sun, and usually lost to view in the sun's glare, fairly

accurate observations of its positions could be secured only when the planet was near its greatest angular distances from the sun and on the rare occasions when the planet passed between us and the sun's disk. Consequently, observations of the highest accuracy were few in number; and,

2. There were large discrepancies between Mercury's predicted and observed positions, certainly not due to the attractions of any known members of our solar system.

Le Verrier, of Neptunian fame, undertook a systematic investigation of Mercury's orbit, making use of all available observations. His results were derived and published in 1859. His work established that there were peculiarities in the planet's orbital motion which could not be due to the attractions of known masses of matter. Chief among the peculiarities was a slow rotation of the orbit itself. It is best described as a forward motion of the orbit's perihelion amounting to 38 seconds of arc per century.

Le Verrier announced that the outstanding differences between prediction and observation could be produced and explained by the disturbing attractions of an undiscovered planet closer to the sun than Mercury and revolving around the sun in an orbit lying nearly in the plane of Mercury's orbit. The mass of (the quantity of matter in) the hypothetical planet would depend upon its distance from Mercury: if half way between Mercury and the sun, its mass would be two thirds that of Mercury; if further from Mercury, the necessary mass would be greater; if nearer, smaller. A group or "ring" of small planets, instead of one large planet, would serve equally well, provided the total mass of the planetoids were of the same order of magnitude. Le Verrier did not say that such an undiscovered planet or ring of planetoids did exist, but simply that it would account for the observed anomalies. The accuracy of his computations, published in detail, could not be questioned. The recognition of his masterly skill, and the memory of his entirely similar discovery of Neptune, assisted in convincing astronomers quite generally that a planet or group of planets existed. The discovery of the disturbing mass became at once a noted problem.

A body traveling around the sun in a circular orbit whose radius is only one half Mercury's average solar distance would never be more than 12° from the sun as viewed by terrestrial observers. A search for it by ordinary methods would accordingly be fruitless. A body large enough to shine brilliantly on a dark-sky background would be hopelessly lost in the bright sky near the sun. Mercury itself, though running out between 20° and 30° from the sun every few weeks, is seldom seen by any save astronomers; and they know where to look for it in the twilight sky.

Two special methods of discovery were applicable: (1) To detect

the planet projected upon the sun's disk when its orbital motion carried it between us and the sun; (2) to search for it when the sky background was darkened at the time of a total solar eclipse.

Needless to say, a crop of discoverers by the first method grew up without delay. The observer of greatest note was Lescarbault, a rural physician of France. Immediately following the publication of Le Verrier's conclusions, Lescarbault announced that he had observed the transit of an unknown planet across the sun's disk several months earlier. Le Verrier journeyed to Lescarbault's home, investigated all the circumstances of the observation, weighed the evidence and concluded that a real planet had been seen. In fact, so convinced of its reality were many scientific men that the name Vulcan was given to it. Older and later reported observations of the same character, to the number of twenty, were collected by Le Verrier, and those which seemed to be in harmony with each other were made the basis of an orbit. Vulcan was found to be about one third Mercury's distance from the sun, revolving once around the sun in between nineteen and twenty days. In some of the text-books on astronomy appearing in the sixties and seventies, Vulcan was assigned a place in the solar system as conspicuous and as secure as that of Mercury itself.

Now it is probable that every one of the twenty observations referred to was erroneous, though made in good faith. In essentially every case the observer was inexperienced, and used a telescope of insufficient power, or one unprovided with measuring apparatus suitable for determining whether or not the subject observed was in motion across the sun's disk. Even the observation of Lescarbault was in doubt when it later transpired that a Brazilian observer of considerable professional experience was at the same hour studying the region of the sun in question and saw only uniform normal solar surface. The situation was not without its humorous side. For example, a Mississippi Valley weather prophet who saw Vulcan crossing the sun's disk, said it was about "as large as a new [*sic*] silver half dollar"! Many of the observations no doubt referred to small sun spots which, with small telescopes, would look round.

Vulcan was searched for by visual observers at the principal eclipses of the sixties, seventies and eighties. Two noted astronomers at the eclipse of 1878, Watson and Swift, believed that they saw two new planets near the sun. However, the two seen by Watson did not agree with those seen by Swift, and still other astronomers at the same eclipse saw no strange bodies in the same regions. As the assigned locations depended upon the hasty readings of graduated circles, in which one can so easily make errors, in the press and excitement of eclipse conditions, the astronomical world quickly, and no doubt

correctly, concluded that the objects seen were well-known neighboring stars.

The perfecting of dry-plate photography gave renewed interest to the search for Vulcan, both when passing over the solar surface and at times of eclipse. Although the sun has been photographed almost daily during the past twenty years, at one observatory or another, no experienced observer has seriously claimed that his plates recorded an unknown planet crossing the sun. Neither were eclipse searches more successful: the well-known bright stars lying nearly in the direction of the sun were photographed, but no strange bodies. Curiously enough, the optical principles governing the efficiency of cameras in this search were overlooked for many years, and faint objects near the sun—say stars fainter than the fourth magnitude—were not observable, because their images, though formed on the photographic plates, were overwhelmed and buried from sight in the general darkening of the photograph by the bright-sky background. It was not until 1900 that the elements of the problem of photographing faint bodies near the sun were comprehended. While preparing for the eclipse of that year, three astronomers, Professor W. H. Pickering, of Harvard College Observatory, and Messrs. Perrine and Campbell, of the Lick Observatory, independently arrived at the same simple conclusion that the focal lengths of the intramercurial-search cameras should be relatively long, in order to reduce the intensity of the sky exposure on the plates without reducing the intensity of the star images, and thus let the latter be seen on the negative. The principles involved are so simple as hardly to call for elucidation.

Let the two cameras have lenses of equal aperture, say 3 inches, of equal transparency and capable of covering equal *angular* fields of view, say a circle 10 degrees in diameter. Let one be of short focus, 21 inches, and the other of long focus, 135 inches. The powers of the two lenses to record stellar points on the sensitive plates in focus, under good atmospheric conditions, are not very unequal, for the two lenses collect equal quantities of light and condense the light into images of very nearly the same size. Both collect the same quantity of sky light, but the longer-focus camera spreads it (more thinly) over an area $(135)^2/(21)^2 = 41$ times the greater. It is evident that faint-star images hopelessly lost to view on the sky-blackened small plate may be seen with ease on the nearly clear glass of the large plate. We may safely say that the large plate will show images of stars 3 or $3\frac{1}{2}$ magnitudes fainter than the small plate. The same advantage exists for small intramercurial planets as for stars, provided the exposures do not exceed two or three minutes in length, as they seldom do at eclipses. In longer exposures on intramercurial planetoids the advantage would usually be lost, as their rapid (and unknown) motions would cause their

images on the plate to move, slowly with short-focus and rapidly with long-focus cameras, thus drawing them out into trails. With the longer instrument here described, an eight-minute exposure would in general be no more effective than one of four minutes. The most successful instrument for the search in question must compromise between the advantage of long focus in reducing sky density, and the disadvantage of long focus in producing long trails. Shorter exposures, giving shorter trails, may be provided by increasing the diameter of the lens, but this in turn means greater unavoidable optical aberrations in the outer areas of the region photographed, which is a reduction in efficiency. In this as in all instruments, extensive experience and good judgment must combine to decide upon the best compromise-proportions.

Professor Pickering, of Harvard, and Mr. Abbot, of the Smithsonian Institution, used such cameras at the total solar eclipse of 1900. The latter observer was favored with good conditions, in North Carolina, and he secured one photograph of a considerable area surrounding the eclipsed sun. Quite a number of the stars known to exist in this region were photographed; but in the absence of a duplicate photograph of the same region, he could not decide whether certain apparent images on the plate were due to unknown planets, or were defects such as always exist in photographic films.

At the eclipse of 1901, in Sumatra, Mr. Abbot, of the Smithsonian Expedition, and Mr. Perrine, in charge of the Crocker Expedition from the Lick Observatory, were prepared, with four cameras each, to secure duplicate photographs covering a large area extending east and west from the sun. Conditions were unfortunately against the success of Mr. Abbot's plans, but thin clouds at the time of the eclipse let 25 per cent. of the light come through to Mr. Perrine's photographic plates. The area covered in duplicate was 6° x 38°, extending along the direction of the sun's equator, with the sun in the center of the region. The plates recorded 170 well-known stars; and all apparent images not of ordinary stars were proved by the duplicate plates to be defects in the films. In two thirds of the area stars down to the eighth magnitude and many fainter ones were recorded; and in one third the area, covered with thicker clouds, stars were recorded down to the fifth and sixth magnitudes.

At the eclipse of 1905 Mr. Crocker made it possible for me to organize expeditions to Labrador, Spain and Egypt, each equipped with four intramercurial cameras, in addition to apparatus for other lines of research. The details of the twelve cameras were planned by Dr. Perrine, the instruments were constructed under his supervision, and any photographic plates obtained with them at the three stations were to be assigned to him to examine for possible intramercurial-planet images. The Labrador group of four cameras, mounted at the

station by Dr. Curtis, made no contribution because of the severe storm conditions prevailing at the time of totality. The Egyptian cameras, mounted by Professor Hussey, recorded a considerable number of stars, but the sky, though clear in the usual sense, was full of dust, and the sun and the surrounding region covered by the search were at a low altitude. The Spanish cameras, photographing through clouds which permitted only 20 or 30 per cent. of the light to pass, recorded 55 stars down to about the seventh and eighth magnitudes. All suspected images not occupying the positions of known stars were proved to be defects in the films.

The eclipse of 1908 in the South Seas was utilized by the Crocker Expedition to cover a region extending east and west along the sun's equator with duplicate exposures. Notwithstanding interference from rain and clouds at the beginning of totality, clear sky prevailed during the last two thirds of the four critical minutes. Dr. Perrine finds more than 500 images of well-known stars on the plates, and no images of unknown bodies. Stars are recorded down to nearly the ninth visual magnitude.

It is not absolutely certain that intramercurial planets, revolving around the sun in elliptical orbits would be seen in projection entirely within the area $9° \times 29°$ lying along the solar equator and equally east and west of the sun's center, yet there are exceedingly strong reasons to believe such would be the case. The eight large planets and the $650 \pm$ minor planets in our system revolve around the sun in the same direction and, excepting a small proportion of the asteroids, so nearly in the sun's equatorial plane that the parts of their orbit planes lying within the limits for intramercurial planets would be projected upon the photographed area. The central plane of the zodiacal light differs little from the sun's equatorial plane. It is certain, also, that any intramercurial planets originally moving in planes inclined at large angles to Mercury's orbit plane would gradually be compelled by the attractions of Mercury and the other major planets to move in planes inclined at small angles to the ecliptic. The coincidence of the satellite planes in the systems of Jupiter and Saturn, and no doubt of Uranus and Neptune also, with the equatorial planes of these planets is another analogy of some weight. Admitting, for completeness, the hypothesis of an extensive system of small planets moving in planes making a variety of angles with the ecliptic and sun's equator, some would certainly have been caught in the region photographed. A single planet, or a half dozen planets, massive enough to meet the requirements, moving in *any* orbit planes would no doubt have been discovered a generation ago. In view of these facts, there is little reason to fear that any planets effective in disturbing Mercury's motions were north or south of the regions covered by photography.

Inasmuch as planets, shining by reflected light, do not act upon photographic plates so strongly as stars of the same visual magnitude, we may say that exposures which recorded stars down to the ninth magnitude should have recorded planets down to the eighth. From the known brightness, distance from the sun and approximate diameter of a few of the asteroids revolving in space between Mars's and Jupiter's orbits, Dr. Perrine has computed that an average eighth-magnitude intramercurial planet could scarcely be larger than thirty miles in diameter and that roughly a million such bodies, of great density, would be required to supply the disturbing effect observed in Mercury's orbit.

Taking all these points into consideration, I think we may say that the investigations by Perrine, forming a part of the work of the Crocker Eclipse Expeditions from Lick Observatory, have brought the observational side of the Intramercurial Problem, famous for a half century, definitely to a close. It is not contended that no such planets will be discovered in the future; in fact, it would not be surprising, nor in opposition to the opinions here expressed, if several such bodies should be found; but it is confidently believed that any such bodies would fail hopelessly to supply the great mass of material demanded by Le Verrier's theory, as Perrine pointed out in discussing the Sumatra observations of 1901.

On the occasion of a future eclipse of fairly long duration, occurring in the dry season, it might be well to repeat the observations, inasmuch as the instruments are in approximate readiness, and the observations at the three past eclipses were made through thin clouds twice, and with cloud-shortened exposures the third time. The cameras are capable of recording tenth-magnitude stars with three-minute exposures in clear sky. It will not be advisable to use these instruments at the eclipses of the next four years.

There are other chapters, on the theoretical side of the problem, to be entered here.

Professor Newcomb's researches on planetary motions extended much further than Le Verrier's. He found small terms in the motions of *all* the inner planets—Mercury, Venus, Earth, Mars—which are not due to the disturbing attractions of any known masses of matter. The chief discrepancies, aside from the large one found in Mercury's motion by Le Verrier and confirmed by Newcomb,[1] are in the perihelion of Mars, and in the nodes of Mercury and Venus. These outstanding residuals will be tabulated on a later page.

The attractions of any one planet or ring of small planets, sufficient to account for the excess motion of Mercury's perihelion, failed to account for the other discrepancies discovered by Newcomb for the

[1] Le Verrier's discrepancy amounted to 38″, Newcomb's to 41″.

four planets. Satisfactory causes were looked for in a possible ellipsoidal form of the sun, in a hypothetical ring of small planets between Mercury and Venus, in an assumed minute variation in the law of gravitation from the Newtonian inverse square of distances, and in other assumptions, but in vain. One hypothesis, that the finely divided material which gives rise to the zodiacal light (by reflecting the sun's rays) is the responsible disturbing mass, has been discussed several times since the days of Le Verrier and as many times rejected, with one exception.

The exception is Professor Seeliger's recently published investigation. With great skill and with entirely reasonable assumptions as to the form of space occupied by the zodiacal material, and as to the density of the distribution of the material in this space, he establishes that there is sufficient mass to account for the discrepancies in the motions of all the four planets.

The following table exhibits the results of Seeliger's theory in the first column of figures, and the actual results of observation as determined by Newcomb in the second column. The quantities in the third column, which bear the sign ±, are the "probable errors" assigned by Newcomb to his results; and, for the benefit of non-mathematical readers, we may explain that these "probable errors," deduced from the observations themselves, are indications of the uncertainties existing in the quantities to which they are attached. In this table e and i are respectively the eccentricity of the orbit and the inclination of the orbit plane to the ecliptic; and $\Delta\Pi$, $\Delta\Omega$ and Δi are respectively the changes, per century, in the longitude of perihelion, in the longitude of node and in the inclination of the orbit plane, unaccounted for by the attractions of known masses, as in the second column, and produced by the attractions of the zodiacal matter as computed by Seeliger. In the last column are the differences between the Seeliger and Newcomb numbers: in other words, a comparison of theory with actuality. These differences are small. All are within the probable errors in the third column; with one exception, far within these probable errors.

We can not ascribe this remarkable agreement between Newcomb's

		Seeliger	Newcomb		N.-S.
		"	"	"	"
$e \cdot \Delta\Pi$	Mercury	+ 8.49	+ 8.48	± 0.43	− 0.01
	Venus	+ 0.05	− 0.05	± 0.25	− 0.10
	Earth	+ 0.07	+ 0.10	± 0.13	+ 0.03
	Mars	+ 0.59	+ 0.75	± 0.35	+ 0.16
$\sin i \cdot \Delta\Omega$	Mercury	+ 0.65	+ 0.61	± 0.52	− 0.04
	Venus	+ 0.58	+ 0.60	± 0.17	+ 0.02
	Mars	+ 0.23	+ 0.03	± 0.22	− 0.20
Δi	Mercury	+ 0.52	+ 0.38	± 0.80	− 0.14
	Venus	+ 0.17	+ 0.38	± 0.33	+ 0.21
	Mars	− 0.02	− 0.01	± 0.20	+ 0.01

and Seeliger's results to fortunate chance, and it is scarcely possible to doubt that in the zodiacal-light materials lie the causes of the discrepancies referred to. I have little hesitation in venturing the opinion that Seeliger's investigation marks an epoch in the application of Newton's law of gravitation to the motions within the solar system. At one stroke he appears to have removed a group of discrepancies which served as bases for many inquiries as to the preciseness and sufficiency of the Great Law. With all respect to Seeliger's genius and labor, however, scientific caution will value confirmation of his results by other investigators.

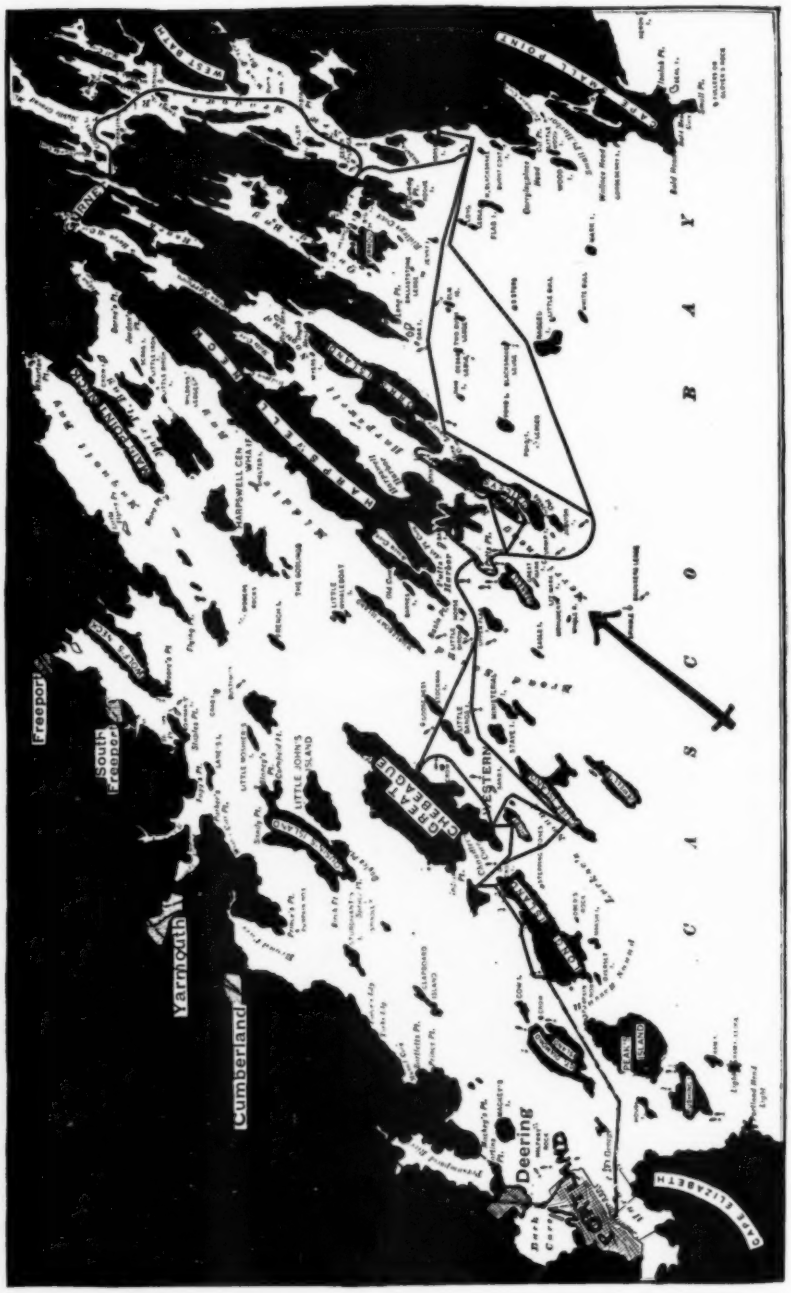
Seeliger's assumptions as to the distribution and mass of the zodiacal material are of interest, especially when we recall that the zodiacal light within some 20 degrees of the sun is unobservable, on account of the glare, and that the brightness of the light is a poor index to the mass: a given quantity of matter, finely divided, would reflect sunlight more strongly than the same quantity existing in larger particles. For the mathematical development of the subject he assumed that the material is distributed throughout a space represented by a much-flattened ellipsoid of revolution whose center is at the sun's center, whose axis of revolution coincides more or less closely with the sun's axis, whose polar surfaces extend 20 or 30 degrees north and south of the sun (as viewed from the earth), whose equatorial regions extend considerably beyond the earth's orbit, and in which the density-distribution of materials decreases as a function both of the linear distance out from the sun and of the angular distance out from the equatorial plane of symmetry. According to these assumptions, surfaces of equal densities are concentric ellipsoidal surfaces, and the number of such ellipsoids can be increased or decreased according as the computer may desire to represent more or less closely any assumed law of density-variation within the one great spheroid. Practically, Seeliger found that the disturbing effects on the planets are almost independent of the law of distribution of the material, as related to distance from the sun, as far out as two thirds of the distance to Mercury. He made use of only two ellipsoids: One with equatorial radius 0.24 unit[2] and polar radius 0.024, of uniform density; and the other with corresponding radii 1.20 and 0.24, of uniform but much smaller density. The total mean densities determined for his volumes, on the basis of unity as the mean density of the sun, are, respectively, 2.18×10^{-11} and 3.1×10^{-15}; and the resulting combined mass of the two ellipsoids is 3.1×10^{-7} of the sun's mass, which is roughly twice the mass of Mercury. The corresponding density of mass-distribution is surprisingly low. In the inner and denser ellipsoid, the matter, if as dense as water, would occupy 1 part in 30,000,000,000 of the space; if as dense as the earth, only 1 part in 160,000,000,000.

[2] The distance from the sun to the earth being 1.00.

The reader should be cautioned against obtaining the impression that Seeliger's two ellipsoids represent the truth as to the law of distribution of density, for such is not the case. A very large number of ellipsoids, doubtless decreasing rapidly in density as one proceeds from the sun outward, would be required to represent the actual law. Seeliger found that the attractive effect of the mass inside of the ellipsoid with maximum radius 0.24 was essentially independent of the law of distribution; and for convenience in the computations he therefore assumed the density in the said ellipsoid to be uniform. A solution based upon a greater number of constituent ellipsoids would perhaps be a slight improvement.

The logic of Seeliger's work rests finally upon the reasonableness of his assumptions and deductions concerning the distribution and density of the zodiacal-light materials; and these are not out of harmony with the meager knowledge of the zodiacal light which we have obtained by direct observation.

In consequence of Seeliger's results further direct observations of the zodiacal light take on renewed interest.



CASCO BAY AND THE SITE OF THE HARPSWELL LABORATORY.

THE HARPSWELL LABORATORY

By MAX MORSE

THE COLLEGE OF THE CITY OF NEW YORK

Whether one is sailing about upon the sunny sea, fishing with muslin nets for the surface fauna, or steaming away far from shore to dredge for other material, or, again, carrying on observations in the cool sea water tanks and bell-jars of a neat little wooden workshop thrown open to the sea-breezes, it alike requires some effort to persuade one's self that the occupation is really something more than that of finding amusement.—Romanes, "Jellyfishes, Starfishes and Seaurchins."

ROMANES was thinking of Cromarty Firth when he drew this beautiful *vignette*. One may equally well think of the "little wooden workshop" founded by John Sterling Kingsley on Casco Bay.

As it stands at present, the laboratory is a one-story, wooden building, 24 by 42 feet on the ground, with sixteen windows looking out directly on a rugged shore, where the long ground swells from open water break incessantly. The building, within, is divided up into nine small rooms for investigators, and one large room, which is fitted up with five tables, for other workers, as occasion demands. A portion of this space is given over to shelving for the nucleus of a library made up mainly of books from the private library of Dr. Kingsley and reprints given to the laboratory by various students. Arrangement is made whereby the current journals are placed on file, during the season, and back numbers may be obtained for the asking, either from Tufts College or from the Boston Society of Natural History. At either end of the laboratory are double doors and when these are "thrown open to the sea breezes" an ideal temperature is assured, even on the warmest days. There have been but few days for many years when the thermometer in the laboratory registered above 78° F.

The equipment of the laboratory, modest as it is, has been found adequate for the purposes. Whenever special apparatus has been called for it has been supplied without delay, either from Portland, which is within an hour and one-half by the line of steamers running down the bay, or from Boston, which may be reached within three hours. Microtomes, glassware and the commoner laboratory materials are brought at the beginning of the season from the zoological laboratory of Tufts College. Investigators, even in our larger laboratories, prefer to take with them their more special apparatus, and such workers have been requested to do so when applying for space at the Harpswell station.

FIG. 1. THE LABORATORY, LOOKING SOUTHEAST. The sea reaches the bluff immediately beyond the fence. The writer is indebted to Professor H. V. Neal for the use of the photographs reproduced in this article.

One feature may appear, to some investigators, a serious drawback, and that is the lack of running water. The experience, however, of those who have carried on protracted series of experiments involving the keeping of living material throughout the season has been that no inconvenience has been felt by the absence of running water. The main reason for this is that the temperature is so low that one may keep material standing in dishes in the laboratory for many days without even changing the water. Thus one may keep hydroids, echinoderms, and even the "candles" of dog-fish without difficulty.

The laboratory is supplied with several small boats and with a motor boat, similar to the one which is used by the fishermen of Casco Bay. It is wonderfully seaworthy and safe, and for the collector it is ideal. If occasion demands, additional motors may be rented at low fees by the day or week from the fishermen. An ample supply of seines, dredges and trawls is maintained at the laboratory. The stock of chemicals and reagents is large, and whenever additional supplies of this character are required they are readily obtained from the larger dealers of Portland, who keep constantly on hand all but the more exceptional reagents. In fact, this city may be drawn upon for supplies rarely found in other cities of its size.

Accessibility to the laboratory is assured. The city of Portland is the terminus of the Grand Trunk System, and of the Boston and Maine and Maine Central railways and of several coastwise lines. The Maine

Steamship Company maintains throughout the year a line of steamers between this port and that of New York. A day line and a night line of steamers ply between Portland and Boston, while the down-east ports, St. Johns and the St. Lawrence country are made accessible by other steamship lines. In general, the rates of passage on these lines is low and there is afforded a most comfortable and convenient mode of travel.

The laboratory is situated in the little fishing village of South Harpswell. A line of steamers sending a boat from Portland every two hours, on the average, throughout the day, is utilized in the main for reaching the laboratory. One may, if he desire, go overland to Brunswick, the seat of Bowdoin College, fourteen miles up Harpswell Neck. From Brunswick, Portland may be reached by trolley or by rail, or by a line of steamers running from the New Meadows River to Portland.

The Portland Public Library and the Library of the Portland Society of Natural History may be called upon for literature not supplied at the laboratory. The latter institution has, too, collections of the animals and plants from the surrounding region, identified by some of our well-known systematists, such as Emerton and others.

It is not, however, the buildings and accessories that attract the worker, but rather the living material. Harpswell has nothing to fear in rivalry with sister laboratories, wherever they may be, in wealth of material. In order to set this feature of the case clearly before the

FIG. 2. INTERIOR OF THE LABORATORY, LOOKING NORTHWARD.

FIG. 3. THE LABORATORY BEACH AT LOW TIDE, looking towards Professor Kingsley's house, immediately beyond which is the laboratory.

reader, it will be necessary to describe briefly the geography of the region.

No geologist has described the rock formation of Casco Bay, although many of the more salient points in its history are evident. A glance at the accompanying map will show that the bay is dotted here and there with islands, none of which are more than three miles in length. It is popularly said by the denizens of the region that there are as many islands in the bay as there are days in the year. However that may be, it seems to the traveler who is making his first visit by the little steamer threading through the devious passages between the islands, that the estimate has been too meager. Extending down from the mainland are several long ragged points of land. Harpswell is one, Cape Small Point is another. The axes of these peninsulas lie parallel with those of the islands and between the islands and the peninsulas are deep lagoons bordered by the steep high sides of the islands. The average depth of these lagoons is fourteen fathoms, although a greater depth is reached in some places. At the westward, Cape Elizabeth forms the boundary for the bay.

A portion of the Arctic current flowing down the Gulf of Maine from the Greenland and Labrador shores is deflected into the immediate vicinity of Casco Bay, giving the cool water and the cool air characteristic of the locality. The Gulf Stream lies beyond this cold current and, while rarely a bit of the fauna of this stream comes into the bay, its effect is practically nothing on the plant and animal life. The dense fogs so characteristic of some of our other laboratories, nearer the Gulf Stream, are nearly absent here. It is mainly for this reason that one may safely use apparatus at the laboratory without injury from rust and hydroxide and oxide depositions. The writer, during the past season, used apparatus of great delicacy, such as is seldom brought out of the city workrooms, in investigating the contractions of muscle in various invertebrates, without any deleterious effect being produced by its sojourn at the coast.

The geological structure of the region is such that the retreating tides leave tide-pools filled with a wealth of animals and plants. The range of the tides is great, averaging fourteen feet. The cleavage planes of the mica schist and slate are normal to each other so that square or rectagonal holes are left for the formation of the tide-pools. Here may be found *Asterias, Strongylocentrotus, Metridium, Tetrastemma, Carcinus, Cancer* and dozens of other species. The algalogist is well rewarded for any labor he may expend in working these pools. The lagoons were gouged out in preglacial times and therefore the rocks are bare and free from till and boulders to a great extent. The subsidence of the whole region in later times has deepened the water throughout the bay, and these deep lagoons are carpeted with immense

Laminaria and the perforated *Agarum,* belonging to the same group. The surfaces of the islands bordering the water stretches and of the peninsulas pushing seaward from the mainland are covered with evergreens, while as one passes up the sounds towards the mainland proper this evergreen growth gives place to deciduous trees. Hence, within a comparatively short distance, the botanist may have a wide range of vegetation.

Out "upon the sunny seas" float *Aurelia flavidula* and *Cyanea arctica* in countless numbers. *Melicerta* and Pteropods occur during

FIG. 4. TYPICAL ROCK STRUCTURE FORMING THE TIDE-POOLS.

the greater part of the season, and these may be collected in a row-boat within the sounds themselves. On shallow banks of sand exposed entirely at low tide *Echinarachnius parma* may be collected in quantities, and with great ease. *Strongylocentrotus dröbachiensis* is dredged by the bushel within a mile of the laboratory, while the same dredgings bring up *Dentalium, Corymorpha, Chalina, Edwardsia, Pentacta, Terebratulina, Pecten tenuicostata, Boltenia* and other classics.

The one-day trips from the laboratory may be undertaken in one of many directions. Twenty miles is generally a recognized limit. The map reveals the possibilities of a day's collecting. All the trips are in

sheltered water or within safe distance of harbors, and the strong tide sweeps which are familiar to the collector at many of our other laboratories are not present here, except in one or two points, hence the fear of being carried away from the collecting ground never disturbs one.

A mile from the laboratory is the site of the Old Tide Mill, now no more, but represented by the rapids which served in former years to turn the wheels of the mill. The open sea is led in communication with a large tidal pond by a long, narrow cove, at the narrowest portion of which the old mill once rested. Through these narrows and over the rocks the tide rushes at twelve knots an hour into the pool at rising tide and out again at falling tide. Beneath these rocks is a veritable curiosity shop for the novice and an Eldorado for the biologist. An invoice from the overturning of a single stone, in genera, is given as follows: *Tethya, Cliona, Tubularia, Clava, Metridium, Asterias, Cribrella, Ophiopholis, Ophioglypha, Strongylocentrotus, Pentacta, Tetrastemma, Lepidonotus, Spirorbis, Membranipora, Balanus, Pagurus, Cancer, Carcinus, Idothea, Purpura, Æolis, Molgula, Leptoclinum* and *Amaroucium*. The most fastidious could scarcely ask for a greater galaxy.

Across the cove and opposite the mill-site is a fishermen's village. Here are brought in, from the open water and the sounds, fish of all descriptions. Aside from the food fishes, such as rock cod, hake, pollock and the like, these men may, at the request of the laboratory, bring back numbers of sand-sharks, rays and dog-fish, the "candles" or egg-cases of which afford possibilities for embryological studies, both descriptive and experimental, hitherto scarcely recognized. The abundance of the material supplied by these fishermen is taken advantage of by Professor F. D. Lambert, who maintains a supply station for zoological material in connection with the laboratory on Harpswell. Nowhere, to the writer's knowledge, is such an abundant supply of choice material made available to the zoologist.

Nearer the laboratory, on the sandy shores of a neighboring island, *Nereis* and *Sipunculus* may be dug in large numbers. *Cerebratulus*, represented by two species, one being the giant form, occurs near the "bridge," while *Balanoglossus, Pholas, Zirphœa* and other interesting and important forms, from the point of view of the experimentalist, are to be found in the same vicinity. But it is impossible to go on. One would of necessity give a catalogue of the fauna of Casco Bay if he desired to do the matter justice.

The history of the laboratory is brief. The late Professor Lee, of Bowdoin College, insisted upon the desirability of establishing a station for the study of marine forms in the Gulf of Maine, and specifically in Casco Bay. In 1898, Professor Kingsley, together with a band of students from Tufts College, leased a cottage near the present site and

FIG. 5. THE COAST AT HIGH TIDE. Compare with Fig. 3.

converted it into a laboratory on the lower floor, while the upper chambers were made living rooms. Then, in 1901, Tufts College bought a tract of land and erected the present building, opening it for the use of students for the first time in the summer of the same year. Later on, an addition was made to the rear of the building. For the first years, undergraduate instruction was maintained in the laboratory, but in 1906, this was abandoned. Now, all the expenses of the laboratory are met from the small fee paid by each investigator, which is made for the use of room and material. For the coming season, a new arrangement has been made whereby funds other than those supplied by the workers will be available and a collector will be ready to bring to the investigator whatever material he may desire. Additions, too, to the library and to the supplies and possibly to the building itself are planned and if not completed during the coming season, they will be made in the near future.

Living facilities, a matter of concern to the average investigator at the summer laboratory, are at their best. One may find almost any mode of living he may desire on Harpswell. If he desires a first-class hotel, he has the choice of three. If he prefer to live in a private house and obtain his meals either in the same house or one within easy access, he may do so. If he desire a cottage, he may obtain one at low rental for the season. The average rental for a five-room house is seventy-five dollars, for the season, beginning as early and ending as late as one desires. Country produce may be engaged and delivered at your door,

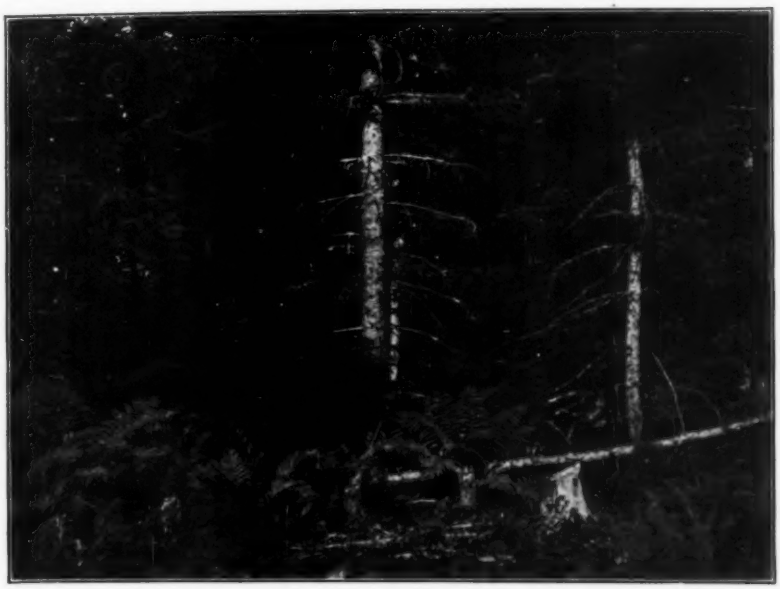


FIG. 6. A VIEW IN THE EVERGREENS, one half mile from the laboratory.

at very reasonable rates, while grocers supply the best provisions, being in the main those brought fresh from Portland, a city well known for its splendid markets. Finally, camping is possible, either near the laboratory, or farther away amongst the evergreens.

With a delightful climate, plenty of sunshine and clear sky, a rich fauna and flora, good facilities for carrying on investigation, a comfortable summer home, freedom from the conventionalities of our more formal stations, ease of access—certainly Harpswell has few rivals.

The biologist is notorious for being ever busy. "I have no vacations," complained an entomologist; "there are ants wherever I go." The ability of the biologist to work incessantly is easily explained; his work is his play. Emphatically is this so of the investigator at Harpswell.

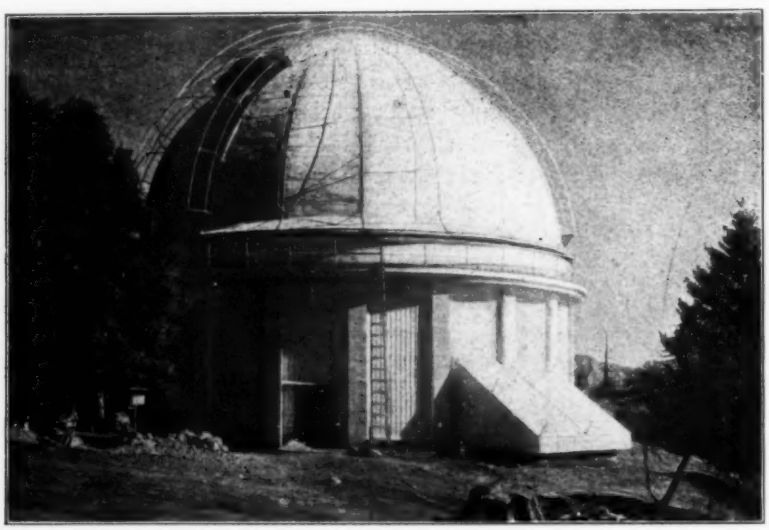
THE PROGRESS OF SCIENCE

THE RESEARCH WORK OF THE CARNEGIE INSTITUTION

THE seventh year book of the Carnegie Institution of Washington, like its predecessors, gives an interesting account of the investigations carried on last year. The work is now in the main conducted by its departments; only a few minor grants are made to scientific men in other institutions, and these are nearly all in continuation of work begun when it was the policy to distribute the larger part of the income in special grants.

The institution has now ten departments, or twelve, if the *Index Medicus* and the horticultural work of Mr. Luther Burbank are included. Two of the principal departments are in astronomy, two in geophysics, three in biology, one in physiology and two in economics and history. The amount of the grants for these departments last year was: astronomy, $105,000; geophysics, $139,000; biology, $70,000; physiology, $35,000; economics and history, $50,000. There was a special grant of $50,000 for publications.

In astronomy the institution conducts the solar observatory on Mount Wilson in California, under the directorship of Dr. George E. Hale, and last year established an observatory in Argentina for meridian astrometry, under Dr. Lewis Boss. The solar observatory has made notable progress in its elaborate installations and has carried forward research work in several directions. The 60-inch reflecting equatorial telescope has been mounted in a new steel dome, and the tower telescope and the horizontal telescope, together with the spectroscopic laboratory in Pasadena, have been in use. The most important work relates to sun-spots and flocculi, giving new results in regard to the constitution and rotation of the sun. The study of the motion and structure of the stellar system has been continued in the Dudley



STEEL BUILDING AND DOME FOR THE 60-INCH REFLECTOR.

THE NUTRITION LABORATORY AT BOSTON.

Observatory at Albany and is now being extended to the southern hemisphere in the observatory erected at San Luis in the Argentine Republic, where the work is under the immediate charge of Professor R. H. Tucker, who has been given leave of absence from the Lick Observatory for this purpose.

The work in terrestrial magnetism under Dr. L. A. Bauer includes the completion of the third cruise of the *Galilee* on the Pacific, where altogether over 60,000 nautical miles have been covered in regions where magnetic data were especially needed. With the extensive work done on land in different countries by the institution and by other agencies a new set of magnetic charts covering nearly one third of the globe can now be constructed. A new magnetic survey yacht is being built, which, on its completion this summer, will be sent to the north Atlantic. The geophysical laboratory at Washington, of which Dr. A. L. Day is director, is now in efficient working order and has entered on a systematic study of rock formation, with excellent equipment for producing such effects of temperature, pressure, etc., as may have occurred in the history of the earth's development.

In biology, the institution supports a desert botanical laboratory in Arizona; a station for experimental evolution on Long Island and a marine biological laboratory in one of the Tortugas Islands. With the desert laboratory at Tucson as headquarters, very interesting experiments are being made on the effects of moisture, altitude, etc., in plants, including a study of the vegetation following the receding area of the Salton Sea. Especially noteworthy have been the experiments of Dr. D. T. MacDougall on the production of new kinds of plants by subjecting the reproductive organs to chemical action. Elaborate experiments in breeding have been carried forward under the direction of Dr. C. B. Davenport at Cold Spring Harbor, Long Island, including the crossing of poultry, canaries, cats, sheep, goats, insects and plants, and observations on human traits, which give quantitative data of importance for determining the laws of heredity. The station at Dry

Tortugas, under Dr. A. G. Mayer, offers admirable facilities for marine biological work of certain kinds of which some ten investigators took advantage.

The nutrition laboratory, under Dr. F. G. Benedict, was last year in the stage of construction and equipment. It is adjacent to the Harvard Medical School and several hospitals, which will give opportunity to work with pathological cases. In the new building, shown in the accompanying illustration, work is now beginning with the calorimeter and in other directions.

The work of the institution in economics, sociology and history has consisted in the collection of data and the classification of records. The department of economics and sociology has suffered through the recent death of the director, Dr. Carroll D. Wright. No work, or hardly any, has been done in anthropology, psychology, philology, literature or art.

Some twenty-four publications were issued by the institution during the year at a cost of about $64,000. The administration building at Washington, erected at a cost of about $220,000, at the southeast corner of Sixteenth and P streets, is now nearly ready.

LIEUTENANT SHACKLETON'S ANTARCTIC EXPEDITION

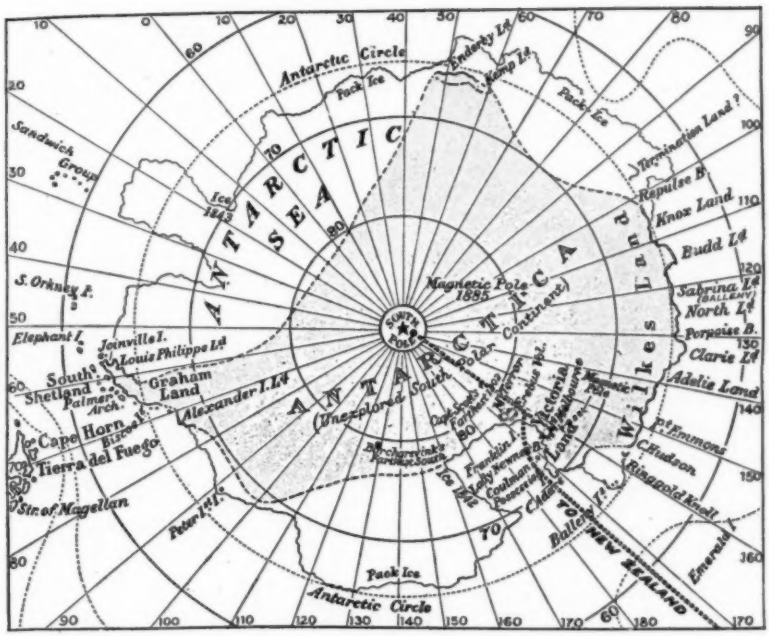
LIEUTENANT SHACKLETON'S expedition has been remarkably successful, whether viewed as adventure or as scientific exploration. The results are the more noteworthy in view of the unofficial character of the expedition and its somewhat modest outfit. The expedition seems throughout to have been accompanied by that kind of good fortune which may properly be attributed to expert knowledge and skilful foresight.

The *Nimrod*, it may be remembered, left New Zealand on January 1, 1908, and included in its scientific staff Professor Edworth David, F.R.S., of Sidney University, and Lieutenant Adams, R.N.A., geologists; Sir Philip Brocklehurst, surveyor and map-maker, and other scientific men. It had been Lieutenant Shackleton's intention to find a convenient place on King Edward's Land at the eastern end of the ice barrier, but the conditions were unfavorable, and it was necessary to take up quarters in McMurdo Sound, close to the place occupied by the *Discovery* in 1902.

The first expedition started on March 5 and ascended Mt. Erebus, the great Antarctic volcano, the summit of which, at an altitude of 11,000 feet, was reached on March 10. It was ejecting vast amounts of steam and sulphurous gas to a height of 2,000 feet.

The Antarctic winter was made use of for collections, observations and photographs. In the early spring, three exploring parties set out, one under Mr. Armitage going westward, gathering geological and topographical data; the second under Professor David going southward and reaching the magnetic pole on January 16 in latitude 72° 25″ and longitude 154° east. The party journeyed 1,260 statute miles in a hundred and twenty-two days, suffering many hardships and making important discoveries.

The most dramatic expedition, in which Lieutenant Shackleton was accompanied by Messrs. Adams, Marshall and Wild, left Cape Royd on November 29, taking with them four ponies. On December 26 they reached the *Discovery* expedition's southernmost latitude. Proceeding south and southeast they reached a high range of mountains and discovered a glacier 120 miles long and forty miles wide, which they ascended, contending with deep crevasses. On December 8 they discovered another great mountain range. On December 26 they reached a plateau at an altitude of 9,000 feet. During this time there was a constant southerly blizzard of wind and drifting snow, with temperature ranging from 37 to 70 degrees of frost. On January 9 they reached latitude 88° 23″ and longitude 162° east, the most southerly point ever attained and 1° 17′ nearer the pole than



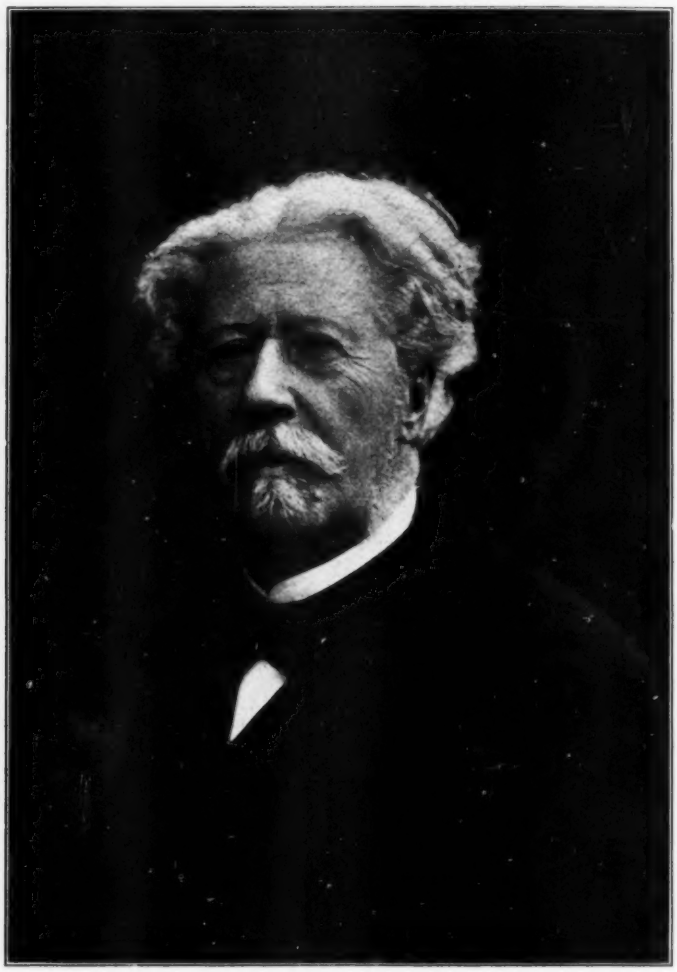
MAP OF THE ANTARCTIC REGION,
Showing the expeditions of the Shackleton parties toward the south geographical pole and to the south magnetic pole.—From the *Independent*.

Peary's farthest north. They were then 111 miles from the south pole, and saw a great plain without mountains stretching towards the south at an altitude of 10,000 or 11,000 feet above sea level. One pony after another had been killed and eaten, and during the latter part of the trip the supply of food had been reduced to a minimum. The return was accomplished with great hardships, the headquarters being reached on March 4, after an absence of 126 days, during which the distance of 1,708 statute miles was covered. Coal measures were found in the limestone, and eight distinct mountain ranges with over 100 peaks were discovered.

TWO GREAT FRENCH NATURALISTS

IN the deaths of Jean Albert Gaudry and Alfred Giard, France has lost two naturalists of distinction, whose contributions to our knowledge of organic evolution were important factors in the most notable scientific advance of the second half of the nineteenth century. They both had in common with their great leader, Charles Darwin, an accurate knowledge of facts in broad fields of the natural sciences and a deep interest in theories and philosophical generalization. They shared fully the quick perception, wide insight and clear expression which are characteristic of French genius.

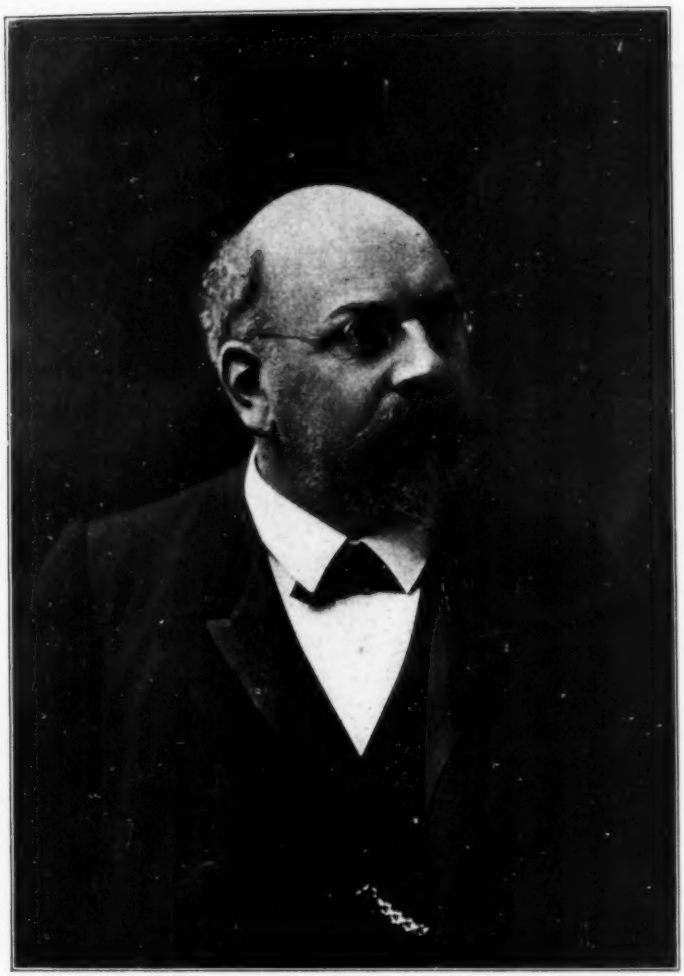
Gaudry was born near Paris in 1827; as a boy he was interested in natural science and the collecting of fossils. At the age of twenty-six he was appointed assistant professor of paleontology in the Paris Museum of Natural History. Before and after the publication of "The Origin of Species" he was engaged in his researches on the late Tertiary vertebrate fauna at Pikermi, near Athens, and on Mont Léberon. His work on the evolution of horses, rhinoceroses and other animals of these regions is of fundamental and classic importance. Other re-



JEAN ALBERT GAUDRY.

searches followed, including work on the Patagonian vertebrates, and much attention was given to the collections of the museum. Wide influence was exerted by his less technical writings in paleozoology and organic evolution.

Giard was born in 1846 in Valenciennes; like Gaudry and so many other naturalists, he was eagerly interested in nature and in collecting as a child. He became professor of natural history at Lille in 1873, and in 1888 there was established for him at the Paris Sorbonne a chair of "evolution of organic beings," a valuable step that should be followed by other universities. In the meanwhile, Giard had in 1874 founded at Wimereux, near Bologne, a marine biological station from which there have been issued not fewer than fifty volumes containing a vast amount of important research. His own work covered nearly the whole range of the biological sciences and extended to botany. Perhaps his work on parasitology is best known, but his researches are encyclopedic in their extent, equally at home in minute details and in broad theories.



ALFRED GIARD.

SCIENTIFIC ITEMS

WE regret to record the deaths of Dr. H. M. Boyè, the chemist, who at the age of ninety-seven years was the only surviving founder of the American Association; of Dr. Persifor Frazer, the chemist and geologist of Philadelphia; of Mark Vernon Slingerland, who held the chair of economic entomology at Cornell University, and of Dr. William Jones, who was killed while engaged in anthropological explorations in the Philippines. Among foreign men of science, we note with regret announcements of the deaths of Dr. Hermann Ebbinghaus, professor of philosophy at Halle, and of Professor Arthur Gamgee, F.R.S., the physiologist.

THE centenary of the birth of Oliver Wendell Holmes has been celebrated at Harvard University, where he was professor of anatomy and physiology from 1847 to 1882.—Congress has appropriated $5,000 for the erection of a memorial to Major J. W. Powell, on the brink of the Grand Canyon of the Colo-

rado, which he explored.—The committee in charge of a fund for a memorial to the late Dr. Andrew J. McCosh announces that more than $100,000 has been subscribed. The fund will be devoted to some portion of the new buildings of the Presbyterian Hospital, with the surgical service of which Dr. McCosh was identified.—It is proposed to endow as a memorial to the late Dr. William T. Bull an institution for surgical research to be connected with the College of Physicians and Surgeons, Columbia University.

THE Royal Academy of Stockholm has presented Mr. Thomas A. Edison with its Adelskiold gold medal for his inventions in connection with the phonograph and the incandescent light. This medal is conferred once in ten years.—The ambassadorship to Great Britain has been offered to President Eliot after his retirement from the presidency of Harvard University, but it is said that he is not likely to accept.

IT is announced that President Taft has requested Surgeon General Wyman to draw up a tentative plan for the consolidation under one bureau of the agencies exercised by the federal government for the preservation of the public health.